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Technical Rules for Hazardous Substances	Substitute Materials for Aluminium Silicate Wool Products	TRGS 619

The Technical Rules for Hazardous Substances (TRGS) reflect the state of the art, the state of occupational health and occupational hygiene as well as other sound work-scientific knowledge relating to activities involving hazardous substances including their classification and labelling. The

Committee on Hazardous Substances (AGS)

compiles or adapts the rules, and they are announced by the Federal Ministry of Labour and Social Affairs (BMAS) in the Joint Ministerial Gazette (GMBl).

These technical rules set out in concrete terms the requirements of the Hazardous Substances Ordinance within their scope of application. If the technical rules are adhered to, the employer can assume that the corresponding requirements under the ordinance have been fulfilled. If the employer chooses another solution, that solution must achieve at least the same level of safety and health protection for employees.

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*) Note: TRGS 619 has been revised and adapted according to the current state of the art. This became necessary due to newly developed materials and products in recent years, extending and adding to the options for substitution. This applies in particular to the field of refractory products that provide a high level of thermal insulation.
The structure of the technical rules has essentially been retained, especially with regard to the tables in Annexes 1 to 3, which provide the user with detailed assistance for the selection of substitutes. Editing centred around the revision of these annexes, whereby information was added on their application, as well as a reorganisation of the terminology.
TRGS 619 was also adapted according to the current Hazardous Substances Ordinance and TRGS 600 “Substitution”. Corresponding adaptations and/or cross references were incorporated in order to take account of the close link between these technical rules and TRGS 558 “Activities involving high-temperature wool”.

1 Scope of application

(1) These technical rules explain the possibilities for substitution of products made of amorphous aluminium silicate wool[1)], which are primarily used for thermal insulation in furnace and incinerator construction, heating systems and exhaust systems in motor vehicles, especially for application temperatures above 900 ºC.

(2) These technical rules do not consider the following fields of application, in which products made of aluminium silicate wool have already largely been substituted:

1. domestic appliances
2. fire protection.

(3) Glass and rock wools are used for the purpose of thermal insulation in the temperature range up to 600 °C and are not dealt with further in these technical rules.

(4) Substitution is intended to eliminate or reduce to a minimum the hazard entailed in activities involving hazardous substances. It is a matter of priority for the protection of employees in the event of activities involving hazardous substances. The recommendations for substitution listed in these technical rules were developed in accordance with the approach described in TRGS 600 “Substitution”. As a general rule, these must be followed during operation in accordance with the general provisions of TRGS 600 (especially number 5, “Decision on substitution”).

(5) These technical rules set out in concrete terms the general statements of TRGS 600 with regard to the substitution of aluminium silicate wool.

2 Definitions

(1) These technical rules use terms as they are defined in the “Begriffsglossar zu den Regelwerken der Betriebssicherheitsverordnung (BetrSichV), der Biostoffverordnung (BioStoffV) und der Gefahrstoffverordnung (GefStoffV)” [Glossary of Terms for the Regulations of the Ordinance on Industrial Safety (BetrSichV), the Biological Agents Ordinance (BioStoffV) and the Hazardous Substances Ordinance (GefStoffV)] of the AGS and ABS[2)].

(2) Within the meaning of these technical rules, fibrous dusts are dusts that can be released from products containing synthetic mineral fibres. For this purpose, the rules take into consideration fibres longer than 5 µm, with a diameter less than 3 µm and with a length–diameter ratio greater than 3 to 1 (WHO fibres).

(3) High-temperature wools (HTWs)[3)] are amorphous aluminium silicate and AES wools (high-temperature glass wools), as well as polycrystalline wools (PCWs).

(4) Aluminium silicate wool, previously also known as ceramic fibres (Refractory Ceramic Fibre = RCF), consists of amorphous fibres produced by melting a combination of Al_2O_3 and SiO_2, usually in a 50:50 weight ratio (see also VDI 3469 Sheet 1 and Sheet 5 and TRGS 558). They can additionally include ZrO_2. Aluminium silicate wool products are mainly used at temperatures > 900 ºC and primarily in equipment that operates intermittently and in intermittent application conditions.

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1) CAS No. 142844-00-6; index number 650-017-00-8 in Annex VI Part 3 Table 3.1 of Regulation (EC) No. 1272/2008 on classification, labelling and packaging of substances and mixtures
2) www.baua.de/de/Themen-von-A-Z/Gefahrstoffe/Glossar/Begriffsglossar.pdf
3) DIN EN 1094-1, “Insulating refractory products – Part 1: Terminology, classification and methods of test for high temperature insulation wool products”

(5) AES wools[4)] (alkaline earth silicate wools = high-temperature glass wools) consist of amorphous fibres produced by melting a combination of CaO, MgO and SiO_2 and are intended for high-temperature applications. AES-wool products are generally used at application temperatures of up to max. 1200 °C and in continuously operating equipment and domestic appliances.

(6) Polycrystalline wools[5)] (PCWs) consist of fibres with an Al_2O_3 content > 63 wt. % and a SiO_2 content < 37 wt. %; they are produced from aqueous spinning solutions in the “sol-gel method”. The water-soluble green fibres formed initially as a precursor are then crystallized by means of heat treatment (see VDI 3469 Sheet 1 and Sheet 5). Polycrystalline wools are generally used at application temperatures > 1300 ºC and in critical chemical and physical application conditions.

(7) Light[6)], fibre-free refractory products are non-metallic ceramic materials. Frequently used materials include, for example, light refractory clay, perlite, vermiculite, expanded clay or hollow-sphere corundum. A differentiation is drawn between unshaped and shaped products:

1. Unshaped products (e.g. concretes, compounds) are given their final form by casting, pounding or spraying while adding a binding agent and are heat-treated after installation. Unshaped products also include mortar and cement.

2. Shaped products (e.g. bricks, blocks, moulded parts) have a defined geometry and are ready for installation. They have largely already undergone heat treatment.

(8) Light, fibre-free refractory products made highly porous by the addition of pore forming agents are non-metallic ceramic materials. These are produced either by foaming or by chemical-thermal processes. The main constituents are, for example, aluminium oxide, mullite and microporous calcium hexa-aluminate.

1. Unshaped products (e.g. concretes) made highly porous by the addition of pore forming agents are given their final form by casting or spraying while adding a binding agent (e.g. water) and are heat-treated after installation.

2. Shaped products (e.g. bricks, blocks, moulded parts) made highly porous by the addition of pore forming agents have a defined geometry and are ready for installation. They have largely already undergone heat treatment.

(9) Fibre-free refractory filler materials are non-metallic ceramic materials (e.g. perlite, vermiculite, expanded clay) that are free of binding agents and are used as a loose filler.

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4) CAS No. 436083-99-7; index number 650-016-00-2 in Annex VI Part 3 Table 3.1 of Regulation (EC) No. 1272/2008 on classification, labelling and packaging of substances and mixtures

5) CAS No. 675106-31-7

6) DIN EN 1094-2, “Insulating refractory products – Part 2: Classification of shaped products”

3 Determination of possibilities for substitution

The employer must always check what hazards can arise during the use of refractory products. The substitution solution must achieve an overall reduction in the hazards posed by hazardous substances in the workplace. At the same time, it should not lead to an increase in other hazards in the workplace or to an increased impairment of other protected goods (e.g. fire and explosion hazards, furnace breakouts accompanied by the escape of molten material).

3.1 Hazardous properties of fibrous dusts from high-temperature wools and resulting hazards for workers

(1) Elongated particles have a carcinogenic effect if they are sufficiently long, thin and biostable. Fibres that meet the criteria under number 2 paragraph 2 are deemed to be sufficiently long and thin (critical fibres).

(2) Potentially carcinogenic fibrous dusts can be released during activities involving aluminium silicate wools and polycrystalline wools.

(3) According to current scientific knowledge, a risk of cancer cannot be ruled out in the event of inhalation of these fibrous dusts. The fibrous dusts released are assessed as a category 2[7)] or category 3[8)] carcinogen in accordance with TRGS 905 “List of substances that are carcinogenic, mutagenic or toxic for reproduction”.

(4) Accordingly, fibrous dusts from aluminium silicate wools (ASWs) are to be assessed as category 2 carcinogens (substances which are to be regarded as carcinogenic for people. There are sufficient indications for the assumption that exposure of a human to the substance may cause cancer).

(5) Within the meaning of TRGS 905, under the term “all other inorganic fibre dusts” (number 2.3 para. 6 of TRGS 905), fibrous dusts of polycrystalline wools (PCW) are to be assessed as category 3 carcinogens (substances that are of concern because of a possible carcinogenic effect on people, but about which there is insufficient information for a satisfactory evaluation. Suitable animal experiments have yielded a number of indications, but this is not sufficient to classify a substance as belonging to category 2).

(6) Fibrous dusts from AES wools are not classified as carcinogenic.

(7) TRGS 558 “Activities involving high-temperature wool” describes protective measures for activities involving high-temperature wools.

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7) Category 2 carcinogen acc. to Annex I No. 4.2.1 of Directive 67/548/EEC (Dangerous Substances Directive) and/or category 1B acc. to Annex VI No. 3.6 of Regulation (EC) 1272/2008 (CLP Regulation)

8) Category 3 carcinogen acc. to Annex I No. 4.2.1 of Directive 67/548/EEC (Dangerous Substances Directive) and/or category 2 acc. to Annex VI No. 3.6 of Regulation (EC) 1272/2008 (CLP Regulation)

3.2 Principles for substitution

(1) Employers are obliged to ensure that any risk posed to the health and safety of employees by a hazardous material in the workplace is eliminated or minimized by the measures defined in the risk assessment. To meet this obligation, the employer should preferably arrange for the substitution of the hazardous material.

(2) In particular, the employer should avoid activities involving hazardous materials or should substitute hazardous materials with substances, mixtures, products or processes that are not hazardous or less hazardous to the health and safety of employees in the respective application conditions. As a matter of priority, the employer must check whether a substitution is technically possible for products made of aluminium silicate wool.

(3) In accordance with paragraph 1, the descriptive profiles for substitute selection as required by sections 6–9 of the Hazardous Substances Ordinance set out in annexes 1, 2 and 3 of these technical rules must be consulted for the selection of possible substitutes.

(4) A substitution should be examined within the framework of an overall assessment based on the entire lifecycle of the possible products used. Products made of aluminium silicate wool must always be substituted if

1. the technical properties (application temperatures, thermal-insulation properties, long-term behaviour and service life) are equivalent and

2. lower overall health risks exist for employees throughout the entire life cycle.

(5) Further reasons for considering the use of substitute solutions can include costs, environmental-protection aspects and energy and resource efficiency (see Annex 3 to TRGS 600). It must be emphasized, however, that higher costs incurred for a substitute solution do not automatically result in a “do not use” assessment. In particular if the substances to be substituted pose a high risk, greater weight must be attributed to the reduction of risk.

(6) The result of the substitute selection must be documented in the risk assessment and disclosed to the competent authorities on request.

3.3 Criteria for the technical suitability and for the health risk of substitutes

3.3.1 General remarks

(1) High-temperature processes involving aluminium silicate wool products vary widely in nature, even within the same industry, and are often highly application-specific. Recommendations for substitution cannot therefore be generalised. In principle, the following technical parameters must be considered:

1. thermal properties,

2. mechanical properties,

3. chemical and mechanical stability,

4. energy and resource efficiency.

(2) Products that do not contain fibres classified as category 1 or 2 carcinogens while satisfying the requirements with regard to application temperature and other application

conditions (see descriptive profiles in annexes 1 to 4) can be used as fibrous substitutes with a lower health risk.

3.3.2 Application temperature

(1) Suitable substitutes for aluminium silicate wool are selected in an initial step using the characteristic of thermal properties (Annex 4).

(2) Glass and mineral wools are generally used at temperatures of up to 300 °C. The temperature range from 300 ºC to approx. 600 ºC can, depending on requirements, be covered by mineral wools or AES wools. From 600 ºC to approx. 900 ºC, products made of AES wools can generally be used.

(3) The option to use products made of AES wools diminishes above 900 ºC and up to approx. 1,100 ºC due to application-specific characteristics. Above approx. 1,200 ºC, products made of AES wools can no longer be used and products made of aluminium silicate wool can only be used to a limited extent.

(4) Products made of polycrystalline wool (PCW) can be used at temperatures of up to approx. 1,650 ºC.

(5) Light, fibre-free refractory products are frequently used as substitutes between 600 ºC and 1,700 ºC, and in special cases at higher temperatures. These products are less suitable for frequent temperature changes during application. The bulk density, which lies between 400 and 1,500 kg/m³, can have a decisive influence on their economical use.

3.3.3 Occurrence of silicogenic dusts

New, fibre-free refractory materials, as well as certain substitutes, can contain crystalline SiO_2 and can release quartz dust during working and processing. In addition, when AES and aluminium silicate wools are exposed to temperatures above 900 °C, crystalline SiO_2 can form, which can be released as silicogenic dust during maintenance and demolition work. Activities involving exposure to crystalline silicon dioxide in the form of quartz/cristobalite are carcinogenic within the meaning of TRGS 906 “List of carcinogenic activities or processes according to article 3 paragraph 2 no. 3 of the Hazardous Substances Ordinance”. In such cases, the rules set out in TRGS 559 “Mineral dust” must be observed.

3.4 Overview of possibilities for substitution

Whether a substitute for aluminium silicate wool is technically possible can be determined using the tables in Annex 1 “Industrial high-temperature processes (e.g. industrial furnace and incinerator construction)”, Annex 2 “Heating systems” and Annex 3 “Exhaust systems in motor vehicles”. It might be necessary to draw upon the expertise of manufacturers, suppliers or other specialists with knowledge of aspects of substitute selection.

3.5 Approach to the selection of possibilities for substitution

Substitutes are selected specifically for the application and using the respective tables in annexes 1–3:

1. In the column “Requirements for the specific application”, it must first be defined whether the listed criteria and/or technical properties are relevant to the specific operational application. The outcome of the assessment is to be documented for numbers 5 to 7 by ticking “Yes” or “No”.

2. In cases where the decision is “No” (i.e. not relevant to the specific application), all materials listed in the table are, in principle, suitable (see e.g. number 7.2 in the table in Annex 1 “Continuous operation, electric, no corrosive furnace atmosphere”).

3. In cases where the decision is “Yes” (i.e. criteria that are relevant to the specific application), the employer must determine which of the listed materials can meet the operational requirements.

4. The materials' suitability with regard to one of the listed criteria can vary. The “+” and “-” signs given in the columns assigned to the materials indicate the degree of suitability. Explanations on these can be found in the legend below each table.

5. After the details and assessments have been completed for the criteria in the described way and an overall assessment has been made of the results, the evidence is provided of whether and how the products made of aluminium silicate wools can be replaced.

6. At the same time, the employer receives information as to which of the materials listed in the table could be suitable as substitutes with regard to the employer's operational requirements.

7. Where applicable, tests (e.g. on chosen sample areas) are necessary to determine the suitability of refractory products as a substitute in practice.

Literature

[1] Ordinance on protection against hazardous substances (Hazardous Substances Ordinance – GefStoffV) of 26th November 2010

[2] TRGS 400 “Risk assessment for activities involving hazardous substances”

[3] TRGS 558 “Activities involving high-temperature wool”

[4] TRGS 559 “Mineral dust”

[5] TRGS 600 “Substitution”

[6] TRGS 905 “List of substances that are carcinogenic, mutagenic or toxic for reproduction”

[7] TRGS 906 “List of carcinogenic activities or processes according to article 3 paragraph 2 no. 3 of the Hazardous Substances Ordinance”

[8] ECFIA website (association of manufacturers and processors of high-temperature wool): www.ecfia.eu and www.ecfia.de

[9] GESTIS Substance Database: http://www.dguv.de/dguv/ifa/Gefahrstoffdatenbanken/GESTIS-Stoffdatenbank/index-2.jsp

Annex 1 to TRGS 619
Industrial high-temperature processes (e.g. industrial furnace and incinerator construction)

Descriptive profile for selecting a substitute for products made of aluminium silicate wools for the purpose of thermal insulation, especially at application temperatures above 900 °C.
Initially, the products that are eligible for the application to be examined should be compared, along with their technical properties (product data sheet), with the requirements in the table. The examination should be carried out with regard, in particular, to the combination of the properties that are relevant to the specific application. The column “Light refractory materials as a possible alternative to aluminium silicate wool” only shows an initial assessment of the products' suitability as a substitute, due to the diversity and wide range of different product variants in the subgroups.

Industrial high-temperature processes (e.g. industrial furnace and incinerator construction)	Officer:	Date:

The values stated in the table are empirical values provided by experts

		Light refractory materials as a possible alternative to aluminium silicate wool							
	Rqmt. for the specific application	**Unshaped**	**Shaped**	**Highly porous, unshaped**	**Highly porous, shaped**	**Filler material**	**AES wools**	**Polycrystalline wools**	**Aluminium silicate wools**
1. Definition[9)]		**(7)1**	**(7)2**	**(8)1**	**(8)2**	**(9)**	**(5)**	**(6)**	**(4)**
2. Application temperature [°C]		up to 1500	up to 1600	up to 1500	750–1500	900–1500	up to 1100	up to 1650	up to 1300

9) The information in this row relates to paragraphs (4) to (9) in no. 2 of these technical rules.

3. Thermal conductivity [10] [W/mK] at **800 °C,** **1000 °C,** **1200 °C**		 0.56 0.68 0.86	 0.32 0.38 0.46	 0.46 0.58 0.76	 0.27 0.33 0.41	 0.1 0.15 -	 0.19 0.27 -	 0.18 0.22 0.26	 0.21 0.31 0.44
4. Density [kg/m³]		400–1500	700–1500	1100	500–1100	150–750	60–300	60–300	60–300
5. Mechanical strength									
5.1 Required	yes/no	+/-	+/-	+/-	+/	-	-	-	-
5.2 Resilience:									
a) in new state	yes/no	-	-	-	-	-	+	++	++
b) after exposure to application temperature	yes/no	-	-	-	-	-	-	++	++
c) expansion joints	yes/no	required	required	required	required	not required	not required, compensation strips if necessary	not required, compensation strips if necessary.	not required, compensation strips if necessary
5.3 Oscillations/vibrations	yes/no	-	-	-	-	+	+	++	++
5.4 Gas speed > 40 m/s [11]	yes/no	++	++	+	+	-	-/+	-/+	+/-
6. Thermal shock resistance	yes/no	-/+	-/+	-/+	-/+	+	+	++	++

10) The thermal conductivity for the various refractory products depends primarily on their density.
11) To be checked as a function of temperature.

7. Application in high-temperature furnaces									
7.1 Furnace atmosphere									
- neutral/oxidising	yes/no	++	++	++	++	++	+	+	+
- reducing	yes/no	+	+	+	+	+	+/-	+/-	+/-
- moisture/ condensate/ water of crystallisation	yes/no	++	++	++	++	+	-/+	+	+
7.2 Continuous operation									
- electric, no corrosive furnace atmosphere	yes/no	++	++	++	++	++	++	++	++
- electric, corrosive furnace atmosphere	yes/no	+/-	+/-	+/-	+/-	+/-	+/-	+/-	+/-
- gas, no corrosive furnace atmosphere	yes/no	++	++	+	+	++	+	++	++
- gas, corrosive furnace atmosphere	yes/no	+/-	+/-	+/-	+/-	+/-	-/+	+/-	+/-
- fuel oil (EL)	yes/no	+	+	-	-	+/-	+	+	+
- heavy fuel oil	yes/no	+/-	+/-	-	-	+/-	-	-	-
7.3 Intermittent operation									
- electric, no corrosive furnace atmosphere	yes/no	+	+	+	+	+	+	++	++
- electric, corrosive furnace atmosphere	yes/no	+/-	+/-	+/-	+/-	+/-	-/+	+/-	+/-
- gas, no corrosive furnace atmosphere	yes/no	+	+	+	+	+	+/-	+	+
- gas, corrosive furnace	yes/no	+/-	+/-	+/-	+/-	+/-	-	+/-	+/-

atmosphere									
- fuel oil (EL)	yes/no	+	+	-	-	+	+/-	+	+
8. Risk assessment									
8.1 Classification		12)	12)	12)	12)	12)	13)	K 3	K 2 13)
8.2 Dust generation									
- during installation		high	low	high	low	medium	medium	medium	medium
- during removal		high	high	high	high	high	high	high	high
9. Protective measures		TRGS 559 "Mineral dust"					TRGS 558 "Activities involving high-temperature wool"		
10. Disposal		Compliance with state-specific regulations							

Legend:
++ very suitable
+ suitable
+/- mostly suitable
-/+ suitability is questionable
- not suitable

12) The materials might contain crystalline SiO_2, which can be released during machining and processing. The composition must be checked in the individual instance.

13) Crystalline SiO_2 (quartz/cristobalite) can be formed above 900°C; if this is the case, it might be released during maintenance and demolition work.

Annex 2 to TRGS 619
Heating systems

(1) Heating systems are used to heat buildings, apartments and individual rooms. A distinction is drawn between central heating systems and single-storey heating systems.

(2) According to DIN EN 12828, a hot-water heating system consists of the following components:

- heat-generation systems
- heat-distribution systems
- heat-emission systems
- control systems.

(3) The performance classes of heat-generation systems range from the lowest output of 4–5 kW to the highest outputs in the MW region for large residential units or hospitals as a single-boiler system. In terms of the types, a differentiation is drawn between atmospheric burners and burners that use the pressure or suction from a blower to prepare the air–fuel mixture.

(4) Forced-draught burners are standardised according to the European standard EN 267 if the fuel is oil or EN 676 if the fuel is gas.

(5) Free-standing boilers for oil, gas and solid fuels are standardised according to the series of standards EN 303-1, EN 303-2, EN 303-3, EN 303-5, EN 303-7, EN 12953, EN 14394, EN 15034 and EN 15035; flued oil stoves with vaporising burners are standardised according to the standard EN 1.

(6) Gas boilers are classified according to their connection to the exhaust system and/or whether the combustion air is supplied from the room (room-air dependent) or from outdoors (room-air independent). Here, the standards EN 297, EN 483, EN 625, EN 656, EN 677 and/or EN 15502 are applied.

(7) For reasons of occupational safety and environmental protection, different types of thermal-insulation materials are used in heating systems depending on the temperatures that occur. Aluminium silicate wool must not be used in the peripheral area of a heating system, where heat insulation in the low-temperature range (from room temperature to 450 °C) is required. This applies especially to the thermal insulation of piping, hot-water tanks, the outer casing, solar systems in the area of the collectors, and the outer fittings. In these areas, polyurethane must be used up to approx. 90 °C and glass and mineral wool up to 450 °C.

(8) In terms of the process technology, openings in the combustion chamber to the outside, e.g. boiler door, inspection opening, door seals and burner flange gasket, must be sealed with glass-fibre products.

(9) In addition, aluminium silicate wool must not be used for thermal insulation of the flue-gas collector box.

(10) In the areas of the heating system in which the flame comes into direct contact with the thermal insulation, it is not always possible to substitute products made of aluminium silicate wool without compromising the system's service life. Replacement of the thermal-insulation products in the end user's home must be avoided.

Descriptive profile for selecting a substitute for aluminium silicate wool products for thermal insulation in heating systems

Heating systems (oil, gas and solid fuels)	Officer:	Date:

	Requirements for the specific application	**Refractory concretes/ bricks**	**Vermiculite standard + modified**	**AES wool products**	**Aluminium silicate wool products**
1. Definition [14)]		**(7)**	**(9)**	**(5)**	**(4)**
2. Application temperature [°C]		up to 1600	up to max. 1300	up to 1100	up to 1300
3. Thermal conductivity [W/mK] at 1000°C		0.38 to 0.68	0.17 to 0.25	0.27	0.31
4. Density [kg/m³]		600 to 1500	400–500	60 to 300	60 to 300
5. Mechanical properties					
5.1 Strength	yes / no	+/-	-	-	-
5.2 Resilience					
a) in new state	yes / no	-	-	+	++
b) after exposure to application temperature	yes / no	-	-	-	++
5.3 Oscillations/ vibrations	yes / no	-	-	+	++
5.4 Sound reduction					
a) sound absorption	yes / no	-	-	+	+
b) sound insulation	yes / no	+	+/-	-/+	-/+
5.5 Gas speed at the thermal insulation/abrasion	yes / no	+	+	-/+	+/-
6. Thermal properties					
6.1 Thermal shock resistance	yes / no	-/+	+	+	++
6.2 Expansion joints	yes / no	required	not required	not required, compensation strips if necessary	not required, compensation strips if necessary

14) The information in this row relates to paragraphs (4) to (9) in no. 2 of these technical rules.

7.	**Application in heating systems**					
7.1	Furnace atmosphere					
	- neutral/oxidising	yes / no	++	++	+	+
	- reducing	yes / no	+	+	+/-	+/-
	- moisture/condensate	yes / no	++	+	-/+	+
7.2	Influence of the fuel					
	- gaseous fuels	yes / no	+	+	+/-	+
	- oil (extra-light oil)	yes / no	+	+	-/+	+
	- oil (heavy oil)	yes / no	+	+	-	-
	- solid fuel	yes / no	+	+	-/+	+
8.	**Risk assessment**					
1.1	Classification		15)	15)	16)	K 2 16)
1.2	Dust generation					
	- in new state		high/low	medium	medium	medium
	- during removal		high	high	high	high
9.	**Protective measures**		TRGS 559 “Mineral dust”		TRGS 558 “Activities involving high-temperature wool”	
10.	**Disposal**		Compliance with state-specific regulations			

Legend:
++ very suitable
+ suitable
+/- mostly suitable
-/+ suitability is questionable
- not suitable

15) The materials might contain crystalline SiO_2, which can be released during machining and processing. The composition must be checked in the individual instance.

16) Crystalline SiO_2 (quartz/cristobalite) can be formed above 900°C; if this is the case, it might be released during maintenance and demolition work.

Annex 3 to TRGS 619
Exhaust systems in motor vehicles

Descriptive profile for selecting a substitute pursuant to sections 6–9 of the Hazardous Substances Ordinance
Description of the tasks and application conditions

(1) Nowadays, exhaust systems of motor vehicles represent a very complex area. It should be noted that, in many detailed areas, several different techniques can be used to meet the statutory emission standards. Accordingly, it is only possible to provide general information on the use of specific materials.

(2) A wide range of exhaust systems are used depending on the vehicle type, mode of operation, engine type, engine management and geometric arrangement of all exhaust-system components from the engine compartment to the exhaust pipe, as well as thermal, mechanical and chemical constraints. The following lists only consider systems and materials that are available on the market.

(3) A basic differentiation can be drawn between so-called hot-end and cold-end systems (see system diagram). In the cold-end systems, i.e. primarily exhaust-silencer systems, it is possible to use exclusively non-classified materials such as mineral or glass wool. Annex 3 to TRGS 619 therefore only deals with hot-end systems.

(4) In hot-end systems, catalytic converters and diesel particle filters in the form of a metallic or ceramic system are used to purify the exhaust gases. The user must select a system from those available to meet the specified criteria of the individual application. Key criteria to be assessed are listed below in alphabetical order:

- ambient temperature load
- chemical and thermal stability
- component strength
- conversion performance
- cost of development
- economic efficiency
- exhaust backpressure
- flexibility
- occupational safety measures
- required space
- recyclability
- separation efficiency (particles)
- weight.

(5) Ceramic systems are mounted with support mats or with a combination of support mats and metal meshes.

(6) Support mats for ceramic catalytic converters and diesel particle filters (substrates) (Table 3.1)

Due to the need to use support mats, it is necessary to assess the various support materials according to the latest technology.

(7) In addition to the parameters stated above, the different expansion properties of ceramic substrates and metal housings, as well as the corresponding canning process, must be taken into consideration for the supporting of ceramic substrates (catalytic converters, DPFs).

(8) If products are used in hot-end systems for the purpose of thermal insulation (Table 3.2), consideration must be made not only of temperature, vibration and atmosphere but also, above all, of the temperature profile in all application cases and areas. Insulation is necessary, on the one hand, to maintain and/or support the function of the components that affect emissions (catalytic converter and particle filter); on the other hand, insulation can be necessary to protect surrounding components from excess temperatures. The components can be thermally insulated inside or outside of the gas-bearing elements.

(9) Possible constraints:

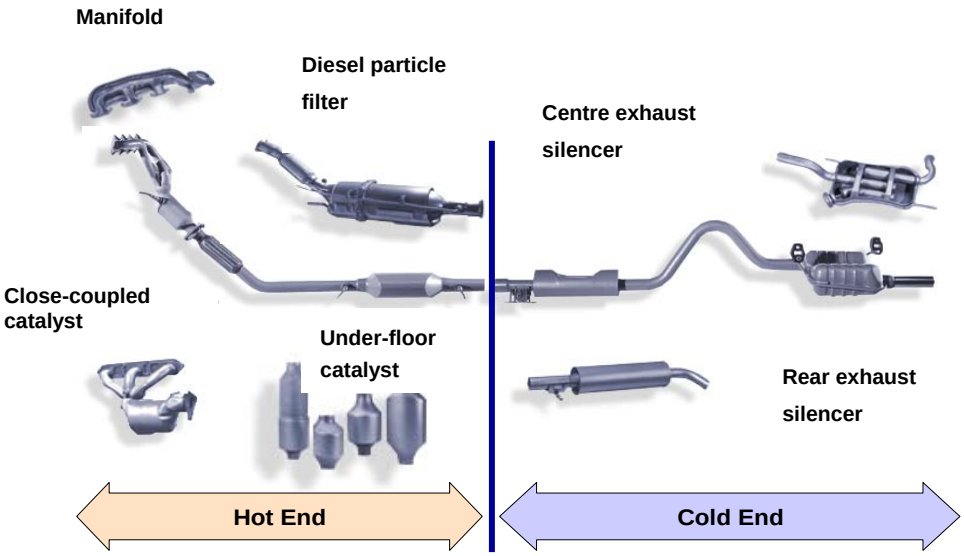
- Temperatures with thermal insulation up to 1,100 °C.
- Temperatures with support mats up to 1,150 °C.
- Temperature peaks with support mats up to 1,200 °C. Absolute temperature gradients from isothermal to approx. 800 °C over the thickness of the mats.
- Vibrations with peak accelerations of up to 120 g (1 g = 9.81 m/s²; acceleration due to gravity).
- Mechanical shocks of up to 150 g.

(10) The parameters stated here can, in principle, be applied to all systems, although the significance of the individual parameters varies from system to system. Example applications include:

Petrol engines:	close-coupled catalyst, CCC
	toe-board catalyst, TBC
	under-floor catalyst, UFC; under-body catalyst, UBC
Diesel engines:	diesel-oxidation catalyst, DOC
	diesel particle filter, DPF
	selective catalytic reduction, SCR
Commercial vehicles:	diesel-oxidation catalyst, DOC
	diesel particle filter, DPF
	selective catalytic reduction, SCR

(11) These elements for post-treatment of exhaust gases can be integrated into exhaust silencers (isothermal application).

(12) The materials used for exhaust systems should be selected to cover the system's entire lifecycle.



Hot end and cold end of an exhaust system

3.1 Selection criteria for application as a **support mat for ceramic substrates**
Officer:

	Application conditions	**Mats with fibres only D >3 µm[18] non-intumescent, amorphous**	**Intumescent mats[19] based on AES wool**	**Intumescent mats[19] based on aluminium silicate wool**	**Non-intumescent mats based on polycrystalline wool**	**Non-intumescent mats based on AES wool**	**Non-intumescent mats based on aluminium silicate wool**
1. Definition [17]		**-**	**(5)**	**(4)**	**(6)**	**(5)**	**(4)**
2. Application temperature (max. surface temperature of the mat) [°C]		600–800	950	950	1150	1000	1050
3. Thermal conductivity [W/mK] [24]							
<600 °C		0.05–0.15	0.05–0.20	0.06–0.18	0.05–0.15	0.05–0.20	0.06–0.15
600–800 °C		TBA	0.15–0.22	0.10–0.22	0.10–0.18	0.15–0.22	0.12–0.20
800–1000 °C		TBA	0.17–0.27	0.12–0.28	0.12–0.22	0.17–0.27	0.15–0.25
4. Weight per unit area [kg/m²]		TBA	1.5–5.2	1.5–7.0	0.9–3.0	1.5–4.0	0.9–3.0
5. Mechanical properties							

5.1 Mechanical strength:	yes/no	+/-	+/-	+/-	+	+/-	+
5.2 Resilience [20)]	yes/no						
a) during installation	yes/no	+	+/-	+/-	+	+	+
b) in operation	yes/no	+	+/-	+/-	+	+/-	+
5.3 Oscillations/ vibrations	yes/no	+	+/-	+/-	+	+/-	+
6. Thermal properties							
6.1 Thermal shock resistance	yes/no	+	+	+	++	+	+
6.2 Thermal stability	yes/no	-/+	+/-	+/-	++	+/-	+
7. Application in exhaust systems							
7.1 Atmosphere							
a) neutral/oxidising	yes/no	+	+	+	+	+	+
b) moisture, condensate	yes/no	+	+/-	+/-	+	+/-	+
c) urea [21)]	yes/no	+/-	+/-	+/-	+/-	+/-	+/-
7.2 Thermal design, temperature gradient	yes/no						
a) isothermal	yes/no	+	+/-	+/-	+	+/-	+
b) non-isothermal	yes/no	+	+	+	+	+	+
c) low-temperature range < 300°C (gas) [22)]	yes/no	+	-/+	-/+	+	-/+	+
7.3 Thermal insulation	yes/no	+	+/-	+/-	+	+	+
7.4 Erosion resistance	yes/no	+	+/-	+/-	++	+/-	+
7.5 Suitability for ultra-thin wall substrates	yes/no	+	-/+	-/+	++	+/-	+
7.6 Permeability/gas-tightness of the support mats		+	+	+	+	+	+
8. Risk assessment							
8.1 Classification		[23)]	[23)]	K2 [23)]	K3	[23)]	K2 [23)]
8.2 Dust generation							
- during installation		low	low	low	low	low	low
- during removal		medium	medium	medium	medium	medium	medium
9. Protective measures		TRGS 558 “Activities involving high-temperature wool” TRGS 559 “Mineral dust”					
10. Disposal		Compliance with state-specific regulations					

Legend:
++ very suitable
+ suitable
+/- mostly suitable
-/+ suitability is questionable
- not suitable

17) The information in this row relates to paragraphs (4) to (9) in no. 2 of these technical rules.

18) According to the WHO definition, fibres with a diameter > 3 µm are not considered to be a health concern.

19) Intumescent mats function based on the volume increase of raw vermiculite under a thermal load. For this purpose, the mat must be operated within a defined temperature range. If the temperatures are too low, the vermiculite does not expand; if the temperatures are too high, the vermiculite melts.
20) Resilience during operation is the most essential property, especially for a support mat. This is determined primarily by the temperature, as well as the temperature profile and curve, the atmosphere, and the relative gap change. The system can only be regarded as assured if resilience can be maintained above a critical level.
21) Insufficient long-term experience available.
22) In the case of mats containing binders (generally organic binder systems), the design of the application must make provision for the binder system and the application temperature, as the decomposition of the binder can have adverse effects on the retention force.
23) Crystalline SiO_2 (quartz/cristobalite) can be formed above 900°C; if this is the case, it might be released on decomposition.
24) Values are a function of the installation density and can vary in the individual case.

3.2 Selection criteria for application **as thermal insulation in hot-end systems**
Officer:

	Application conditions	Materials with fibres only D > 3 µm [26] non-intumescent, amorphous	Materials based on AES wool	Micro-porous silica	Materials based on poly-crystalline wools	Materials based on aluminium silicate wool
1. Definition [25]		-	(5)	-	(6)	(4)
2. Application temperature (max. surface temperature of the thermal insulation) [°C]		950	1050	1050	1150	1100
3. Thermal conductivity [W/mK] [31] <600 °C 600–800 °C 800–1000 °C		0.05–0.15	0.05–0.20 0.15–0.22 0.17–0.27	0.01	0.05–0.15 0.10–0.18 0.12–0.22	0.06–0.18 0.10–0.22 0.15–0.28
4. Weight per unit area [kg/m²]		TBA	1.5–3.5	TBA	0.4–3.0	0.4–3.0
5. Mechanical properties						
5.1 **Mechanical strength:**	yes/no	+	+	-/+ [27]	+	+
5.2 Resilience:						
a) during installation	yes/no	+	+/-	-/+ [27]	+	+
b) in operation	yes/no	+	+/-	-/+ [27]	+	+
5.3 Oscillations/vibrations [28]	yes/no	+	+	-/+ [27]	+	+
6. Thermal properties						
6.1 Thermal shock resistance	yes/no	+	+	+	++	+
7. Application in motor-vehicle exhaust systems						
7.1 Atmosphere						
a) neutral/oxidising	yes/no	+	+	+	+	+
b) moisture/ condensate	yes/no	+	+/-	-/+ [27]	+	+
c) urea [29]	yes/no	+/-	+/-	+/-	+/-	+/-
7.2 Thermal insulation	yes/no	+/-	+	++	+	+
7.3 Erosion resistance	yes/no	+	+/-	-/+ [27]	++	+
8. Risk assessment						
8.1 Classification		[30]	[30]	-	K3	K2 [30]
8.2 Dust generation						
- during installation		medium	medium	medium	medium	medium
- during removal		medium	medium	medium	medium	medium
9. Protective measures		TRGS 558 “Activities involving high-temperature wool”				

		TRGS 559 “Mineral dust”
10. Disposal		Compliance with state-specific regulations

Legend: ++ very suitable
+ suitable
+/- mostly suitable
-/+ suitability is questionable
- not suitable

25) The information in this row relates to paragraphs (4) to (9) in no. 2 of these technical rules.
26) According to the WHO definition, fibres with a diameter > 3 µm are not considered to be a health concern.
27) Property can be improved by encapsulation, packaging or other measures.
28) The resistance to vibration and erosion essentially depends on the product shape and must be tested in the individual case. Common product shapes are: mat (needled), felt, paper, moulding (with/without organic binder), encapsulated mats/felts/papers, and mixed materials made of non-classified fibres.
29) Insufficient long-term experience available.
30) Crystalline SiO_2 (quartz/cristobalite) can be formed above 900°C; if this is the case, it might be released on decomposition.
31) Values are a function of the installation density and can vary in the individual case.

Annex 4 to TRGS 619
Temperature ranges for the application of inorganic, synthetic mineral and high-temperature wools based on DIN EN 1094-1