SAFE OPERATION AND MAINTENANCE OF FURNACES INSULATED WITH REFRACTORY CERAMIC FIBRES (RCF)

Doc 207/17

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Prepared by the members of TF-I.11-1- RCF

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1 Introduction

Alumino silicate fibres, also known as Refractory Ceramic Fibres (RCFs), are used for the insulation of high temperature furnaces operated by EIGA members. See EIGA Document 155 [1][1], EIGA Document 183 [2] and EIGA Document 185 [3] for information on the operation of high temperature furnaces

Due to their health hazard characteristics, RCFs have been identified as Substances of Very High Concern (SVHC) according to the REACH Regulation [4]

This document is intended to demonstrate the safe use of RCF in the premises of EIGA members until an acceptable substitute material is found. At the time of publishing this document, no suitable substitute material for all uses of RCF in steam methane reformers had been identified.

2 Scope and purpose

2.1 Scope

This publication covers construction, inspection, normal repair and maintenance of furnaces insulated with RCFs as well as the demolition of the furnaces after decommissioning.

2.2 Purpose

The document describes best practices of EIGA members for the protection of their workers during operation of any fired heater where Refractory Ceramic Fibres are used, including Steam Methane Reformer furnaces. The best practices described in this document were developed for RCF but can also be applied to other high temperature insulation wools.

This document supplements the existing EIGA Document 172 *Combustion Safety for Steam Reformer Operation* [5].

3 Definitions

3.1 Publications terminology

3.1.1 Shall

Indicates that the procedure is mandatory. It is used wherever the criterion for conformance to specific recommendations allows no deviation.

3.1.2 Should

Indicates that a procedure is recommended.

3.1.3 May and need not

Indicate that the procedure is optional.

3.1.4 Will

Is used only to indicate the future, not a degree of requirement.

3.1.5 Can

Indicates a possibility or ability.

[1] References are shown by bracketed numbers and are listed in order of appearance in the reference section.

3.2 Technical definitions

3.2.1 Occupational exposure levels (OEL, IOELVs, BOELVs)

- **Occupational exposure limit (OEL)**: An **occupational exposure limit** is an upper limit on the acceptable concentration of a hazardous substance in workplace air for a particular material or class of materials. It is typically set by competent national authorities and enforced by legislation to protect occupational safety and health.

- **Indicative occupational exposure limit values (IOELVs)**: OELVs published by the Commission in application of the Chemical Agents Directive [6]. Member States shall establish national occupational exposure limit values taking into account the Community values.

- **Binding occupational exposure limit values (BOELVs)**: OELVs published by the Commission. For any chemical agent for which a BOELV is established, Member States should establish a corresponding national binding occupational exposure limit value based on, but not exceeding, the Community limit value.

4 Identification and characteristics of High Temperature Insulation Wool (HTIW)

4.1 Overview of HTIW

RCFs are one of a number of HTIW. RCFs are used in applications where other HTIWs cannot be used due to temperature, environment, etc.

HTIW fibres have different hazard classifications due to their differing characteristics. Inhaled fibres can be dangerous because they may be breathed deep into the lung and resist the body's attempts at removal. If they persist in the lungs for a sufficiently long time and in sufficient quantities, they can cause damage by irritation and inflammation and eventually scarring. There are 3 important characteristics that determine the degree of hazard posed by a fibre:

- Dimension – fibre length and diameter.

- Durability – property that determines the extent to which a fibre will withstand the lung's natural removal processes.

- Dose – number of fibres reaching the deep lung, determined predominantly by exposure concentration and fibre diameter.

These characteristics vary between fibre types, meaning that fibres are not all the same with respect to their ability to cause harm.

Exposure to any type of fibres (regardless of classification) requires that proper workplace protection measures and good work hygiene practises should be used when working with all HTIW products. When recommended work practises are adhered to, HTIWs are safe to manufacture, install and use.

For more information see [8].

4.2 RCF - Identification as per ECHA dissemination data and EN 1094-1:2008

RCFs is a generic name that covers both Aluminosilicate Refractory Ceramic Fibres (Al-RCF) and Zirconia Aluminosilicate Refractory Ceramic Fibres (Zr-RCF). These types of fibres have typical composition ranges shown in the following two tables:

Table 1: Aluminosilicate wool composition range

Component	Percentage by mass
Al2O3	46-56
SiO2	44-54
Other oxides	<1

Table 2: Alumino zirconium silicate wool composition range

Component	Percentage by mass
Al2O3	<37
SiO2	>48
ZrO2	<20
Other oxides	<1

Both types of fibres are covered by CAS number 142844-00-6 and fulfil the three following conditions:

a) oxides of aluminium, silicon (and zirconium) are the main components present in the fibres within variable concentration ranges;

b) fibres have a length weighted geometric mean diameter less two standard geometric errors of 6 or less micrometres (µm);

c) alkaline oxide and alkali earth oxide (Na2O+K2O+CaO+MgO+BaO) content less than or equal to 18% by weight.

4.3 Classification of RCF according to CLP

RCFs are classified under index number 650-017-00-8 in Annex VI, part 3, table 3.1 of Regulation (EC) No 1272/2008 (CLP) as **carcinogen, Carc. 1B1 (H350i: "May cause cancer by inhalation").** This classification has been confirmed in the REACH registration dossier

4.4 Localisation and types of use

In reformer furnaces, Refractory Ceramic Fibres are used in locations where the temperature exceeds 1000°C under continuous operation, or is likely to exceed 1100°C during limited periods.

RCFs are installed in the radiant section of the furnace, where the temperature can reach 1200°C locally, and are present at the entrance of the flue gas duct, where the temperature of the flue is close to 1100°C in normal operation. Further downstream, heat recovery cools down the flue gas.

RCFs are present in articles of various forms and shapes according to the needs:

- Compressed modules or blankets in preset dimensions to minimize the need for cutting these items on site. These items are installed on the walls and roof of the combustion chamber and of the flue gas duct.

- Blankets as back-up layer behind compressed modules and the expansion joints of the bricks and blocks.

- Board panels used as back-up layer behind firebricks.

- Vacuum preformed elements: The manufacture of these is carried out in dedicated workshops (outside of the scope of the present paper), and they are only installed on site. Such preformed blocks are used around combustion chamber peepholes.

- Braided ropes installed around catalyst tubes when crossing fixed parts of the furnace. This material allows the movement of the tubes relative to the fixed parts due to thermal expansion.

- Thin ceramic fibre paper used for sealing access doors and for assembly of internally lined equipment (e.g. reformer gas collector). Ceramic paper is available in commercial length and needs to be cut depending on required quantity.

It is recommended that all new plants assemble an RCF register at time of build detailing all the locations within the facility where RCF is installed. This document should be stored in a location easily accessible to the operating and maintenance teams. Existing plants should create and maintain the same register.

Positive material identification techniques shall be employed where uncertainty exists as to the identity of material installed. When in doubt or in the case of RCF mixed with other material, the fibres shall be treated as RCF.

5 Applicable legislation

5.1 European legislation

The use of RCFs is controlled by two sets of legislation:

a) The Occupational Safety and Health legislation, namely the "**C**hemical **A**gents **D**irective (CAD) [6] and the **C**arcinogens or **M**utagens **D**irective (CMD) [7].

   Both directives require employers to conduct workplace specific risk assessments in order to eliminate or minimise risk, preferably by substitution of a non-hazardous or less hazardous process or chemical agent. Under CMD, substitution is mandatory if technically feasible.

   Workplace safety is controlled by providing and maintaining control measures identified in the employer's risk assessment. Control measures include periodic measurements to verify that established occupational exposure levels (IOELVs, BOELVs) are not exceeded.

   At the time of the publication of this document, no EU-wide OEL had been established.

b) The legislation on placing on the market and use of dangerous products, namely the **R**egistration, **E**valuation, **A**uthorisation and **R**estrictions of **Ch**emicals (REACH) [3].

   RCFs have been registered (registration number: 01-2119458050-50-xxxx) before the first deadline of 1 December 2010.

   As of 13 January 2010 RCFs have been included in the Candidate list of Substances of Very High Concern (SVHC).

   REACH requires the progressive replacement of SVHCs from supply and use through authorisation and restriction.

   The REACH registration dossier identifies risk management measures that need to be implemented to show that the relevant "Derived No Exposure Limit (DNEL)" or Derived Minimal Effect Level (DMEL)" will not be exceeded.

5.2 National legislation

The country-specific Occupational Exposure Limit (OEL) shall be identified before activities with potential exposure to RCF are completed. When an EU-wide OEL is established the governing limit shall be determined.

6 Preparation for site works

In general the exposure to fibre dust should be minimized during site activities by the use of equipment and procedures that minimise dust production.

If possible, only products that are preassembled and cut to fit should be used. Products are to be unpacked carefully only after they have arrived at the place of installation or processing; any unnecessary handling of the products shall be avoided.

6.1 Risk analysis

Before the start of work, a risk assessment shall be prepared.

The aim is always the reduction of exposure (level and duration) to RCF. The necessary technical and organisational measures must be carefully implemented.

The risk analysis shall include:

- Description of RCF type and location.
- Identification of all of the tasks likely to generate fibres in the atmosphere: preparation of materials, cutting, installation, dismantling, cleaning and management of waste.
- The hazards associated with each task.
- The remedial measures that will be instituted to control or eliminate any identified hazards.
- Detailed information, including safety data sheets, on the materials to be installed or removed. The quantities of material to be installed or removed shall be identified.

6.2 Site organisation

6.2.1 Before the work

Before start of any work involving RCF, the following information shall be made available:

- Safe work permit with authorized workers list.
- Area where installation work will be performed.
- Changing facilites appropriate to the scope of the work.
- Area dedicated to RCF material storage.
- Transportation route and methods for fibrous materials on the site, especially from the storage area to the furnace.
- Designated RCF work areas (e.g. rest area, material cuttings areas), if different from the zone of installation.

6.2.2 During the work

The access to areas where RCF work is being performed shall be limited to authorized workers,

The work procedures shall intend to limit the dispersion of the RCF fibres inside and outside furnace enclosure and outside any RCFs designated work areas.

6.3 Monitoring of exposed workers

6.3.1 Monitoring exposure at the workplace

Concentration measurements of the atmosphere in accordance to EN 689 [9] should be performed at regular intervals to control the adequacy of the work procedures and to ensure any individual is not exposed to concentrations above the OEL.

6.3.2 Health surveillance

Routine health surveillance shall be performed as per the applicable country's requirement.

6.3.3 Information and training

Before start of any work involving RCF, information and training shall be given to potentially exposed workers, including:

- Potential risks.
- Procedure for reducing dust and fibre emissions.
- Requirements for use of personal protective equipment (PPE).
- Summary of any monitoring that has previously occurred, or which is being conducted, to verify that the PPE and other mitigation measures employed are adequate to meet the OEL.
- Personal hygiene after the work.

7 Site Requirements for activities with potential exposure to RCFs

7.1 Storage of the Refractory Ceramic Fibres

The storage of the RCF must be in a closed area protected from weather and clearly marked as RCF storage.

7.2 Changing facility

An appropriate changing facility (separate to the site locker room) shall be provided, the complexity of which will depend on the tasks that will be completed in and around the furnace. It may be as simple as requiring the removal of disposable outer wear at the work site, or it may be as complex as a dedicated decontamination unit.

As applicable, an access path between the changing facility and the furnace inlet shall be delimited in order to avoid contact between workers exposed to RCF inside the furnace and workers present outside the furnace.

The procedure for access control of the furnace enclosure shall be approved by the HSE (health safety and environment) site coordinator.

7.3 Personal Protective Equipment (PPE)

Possible exposure to RCFs requires a minimum standard of PPE as described below. The risk assessment of the tasks shall define any additional PPE requirements.

- Disposable protective clothing (with hood).
- Disposable smooth gloves.
- Appropriate shoe covers.
- Appropriate safety glasses/goggles (task dependent).
- Respiratory Protective Equipment.
    - Selection of level of respiratory protection required should be based on potential for fiber exposure and on any existing fiber air monitoring data.

- Filtering facepiece FFP3 or half-face APR (Air Purifying Respirator) TM3P for all employees involved in furnace inspection.

- Half-face APR TM3P is the minimum standard for activities that have the potential to release greater amounts of RCF such as installation, maintenance, dismantling, cutting, etc. Greater protection may be required depending on the task risk assessment.

Reusable PPE shall be cleaned after each use. Employees shall not clean PPE at home.

Disposable PPE shall be disposed of as RCF waste. (see next section).

7.4 Waste

All material in contact with RCF (scraps resulting from cutting, RCF items dismantled or removed, filters, disposable PPE, bags of vacuum cleaners, wipes) shall be considered as RCF waste.

Waste RCF shall be stored in dedicated bags. The bags shall be dedicated to RCF materials and shall be kept closed and permanently identified by adequate label. The waste RCF bags shall be stored in a delimited area.

RCF waste shall be consigned for disposal to an authorised waste contractor under waste code *07 02 16* wastes containing hazardous silicones* or according to country rules, based on Directive1999/31/EC [10].

8 Handling requirements

To the extent practical, handling of RCF should be minimized.

8.1 General tasks

8.1.1 Cutting

8.1.1.1 Inside the furnace

As much as possible, the cutting of RCF material shall be performed within the furnace enclosure using manual tools. Personnel should be protected through the use of cut-resistant gloves (e.g. Kevlar).

When cutting RCF blanket and other thin RCF materials, smooth knives shall be used. For cutting compressed RCF blocks or other thick objects, a “fire brick saw” designed for cutting high temperature insulating wool bricks should be used. These specially designed saws feature a straight blade with deep serrations. The design of the serrations enables the RCF block to be cut quickly without causing the block to crumble.

8.1.1.2 Outside the furnace

When cutting is performed outside the furnace, it shall be carried out in a dedicated space that is designated for RCF. If large quantities of RCF must be cut, the designated cutting area should be enclosed. Connecting the enclosure to a vacuum fan with appropriate particle filter should be considered based on task risk evaluation.

A plastic sheet (type polyane) shall be installed on the ground to collect fibres and RCF waste material. The plastic sheet should be replaced as needed to prevent the build-up of RCF material on the walking surface. Alternately, the plastic sheet can be vacuumed (an appropriate particle filter is required), or a wet cleaning process can be used.

The systematic use of manual tools is imperative. Cutting using power tools is not authorized. Smooth blades or manual fire brick saws should be used. Personnel should be protected through the use of cut-resistant gloves (e.g. Kevlar).

Workers shall wear PPE as per 7.3.

8.2 Installation

For all activities related to RCF, the procedures and instructions as stipulated in the operating manual and installation guidelines of the refractory supplier and the OEM shall be followed. In general, the following aspects shall be considered:

- Define the working process in such a way that as little fibre dust as possible is released
- Take organisational protective measures to minimize the number of exposed persons. Only authorized persons should access the working areas. Establish an adequate buffer zone around the furnace. Barrier tape or other means of restricting access shall be considered.
- Collect and cover any RCF material not used or left over during installation.
- Perform a cleaning of the working area at the end of every working day. Use a vacuum cleaner equipped with an appropriate particulate filter. Manual sweeping or the use of compressed air to clean the furnace is not allowed, in order to avoid possible dispersion of RCF dust.

For RCF installation activities, which may also comprise cutting as per § 8.1.1.1, a partial containment of the furnace shall be carried out to avoid the dispersion of fibre dust outside the furnace. The installation of an extraction air fan could be considered, preferably installed on the upper part of the furnace. If used the fan shall be equipped with or connected to a suitable particulate air filter that is disposed after the use according to §7.4.

The majority of openings (peepholes, burners) shall be kept closed where possible, with the exception of some openings close to the lower part of the furnace in order to establish a positive draft from the bottom to the top (direction of the connected extraction air fan). If the majority of furnace openings cannot be closed due to an overriding concern (e.g. heat-related illness), the buffer zone around the furnace shall be adjusted to account for greater dispersion of fibres.

Even if not considered a confined space, the use of a portable oxygen analyser to monitor the atmosphere in the furnace should be considered based on an activity risk evaluation.

8.3 Inspection without any work

Typically, this is a visual inspection of the internal parts of the furnace, without any internal work (in particular no scaffolding) being done.

During internal inspection, the goal is to minimize the uncontrolled release of fibres from within the furnace to outside of the furnace. At a minimum

- When opening furnace doors, avoid opening doors on opposite sides of the furnace at the same time to prevent a path for wind to blow fibres from the furnace.
- If it is required to open doors on opposite sides of the furnace, covering the openings with ballasted plastic flaps helps to reduce draft formation.

The minimum PPE requirements of Section 7.3 apply to visual inspection tasks, although additional PPE may be required to meet company procedures or national/local regulations.

8.4 Maintenance/Repair

Maintenance and repair activities associated with RCF can vary in scope and complexity, with the result that there can be a greater or lesser release of RCF fibres depending on the specific maintenance task and on the extent of the repair. A task that releases a significant amount of RCF fibres that is restricted to a small section of the furnace may require the same safety precautions and PPE as a task that releases fewer RCF fibres but that is being conducted over a large section of the furnace.

Each maintenance task shall be evaluated to determine the appropriate safety precautions. Where available, results from previous RCF fibre monitoring conducted during performance of similar maintenance activities should be utilized when assessing the required safety and PPE precautions. When previous fibre monitoring results are not available, a conservative approach should be taken when evaluating tasks and deciding on safety precautions.

As when conducting installation of RCF, the procedures and instructions stipulated in the operating manual of the refractory supplier and the OEM shall be followed. In general, the following aspects shall be considered:

- Define the working process in such a way that as little fibre dust as possible is released.
- Take organisational protective measures to minimise the number of exposed persons. Only authorized persons should access the working areas. Establish an adequate buffer zone around the furnace. Barrier tape or other means of restricting access shall be considered.
- Collect and cover any unused RCF material.
- Clean the work area at the end of every working day. Use a vacuum cleaner equipped with an appropriate particulate filter. To avoid possible dispersion of RCF dust, manual sweeping or the use of compressed air to clean the furnace is not allowed.

The majority of openings (peepholes, burners) shall be kept closed where possible, with the exception of some openings close to the lower part of the furnace in order to establish a positive draft from the bottom to the top. If the majority of furnace openings cannot be closed due to an overriding concern (e.g. heat-related illness), the buffer zone around the furnace shall be adjusted to account for greater dispersion of fibres. If the release of RCF fibres is expected to be high, an extraction fan with appropriate particulate filter should be installed, preferably at the top of the furnace. The air filter shall be disposed after use according to §7.4.

The use of a portable oxygen analyser to monitor the atmosphere in the furnace should be considered based on an activity risk evaluation.

8.5 Dismantling

All previously described measures to limit personnel exposure shall be taken.

In addition, the following additional measures shall be taken to further reduce exposure:

- The working process shall be selected in such a way that as little fibre dust as possible is released, e.g. non-destructive removal, mobile extraction devices, wetting during demolition work.
- Identify an adequate buffer zone as part of the risk assessment, with due consideration to any previous monitoring results and to the specifics of the job scope and the job site, including ventilation, ambient condition, condition of the refractory and working methods.
- Organisational protective measures shall be taken to minimise the number of exposed persons. Only authorized persons may be granted access to the working areas, including an adequate buffer zone. Barrier tape or other means of restricting access shall be considered.

- Where possible, objects, machines and equipment in the area around the workplace that are difficult to clean shall be covered. Any objects, machines, or equipment within the RCF-affected area that cannot be covered during the dismantling work must be cleaned periodically as well as immediately upon completion of the work. At a minimum, cleaning must be performed on a daily basis.

- Before and during the dismantling of high temperature wool furnace linings and other refractory material, the material to be removed should be wetted, if technically feasible, by atomized water spray. The use of liquid jets is not allowed. When removing furnace linings, low-dust, direct extraction procedures shall be used to the extent feasible.

- High temperature wool material that has been knocked out shall not be left lying in the working areas but shall be collected in plastic bags or in sealable and labelled containers.

9 References

Unless otherwise stated the latest edition shall apply.

[1] EIGA Doc.155 *Best Available Technology for Hydrogen Production by Steam Methane Reforming*

[2] EIGA Doc.183 *Best Available Technology for Co-Production of Hydrogen, Carbon Monoxide, and their Mixtures by Steam Reforming*

[3] EIGA Doc.185 *Safe Start-Up and Shutdown Practices for Steam Reformers*

[4] Regulation (EC) No 1907/2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH),

[5] EIGA Doc.172, *Combustion Safety for Steam Reformer Operation*

[6] Directive 98/24/EC of 7 April 1998 on the protection of the health and safety of workers from the risks related to chemical agents at work (CAD)

[7] Directive 2004/37/EC of 29 April 2004 on the protection of workers from the risks related to exposure to carcinogens or mutagens at work (CMD)

[8] Guidance documents from the European Ceramic Fibre Industry Association (ECFIA) downloadable at http://www.ecfia.eu/products_materials.htm

[9] EN 689, *Workplace atmospheres. Guidance for the assessment of exposure by inhalation to chemical agents for comparison with limit values and measurement strategy*

[10] Council Directive 1999/31/EC *on the landfill of waste*