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TNO Report

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Measurement Protocol for the TNO Worst Case Room

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Contents

1 Introduction

This Measurement Protocol for the TNO Worst Case Room has been developed to enable the objective assessment of tools, including hand tools, and their respective control measures. The assessment concerns the emission of hazardous substances and takes place during operational use. The hazardous substances in question are respirable quartz, sawdust (hardwood), asbestos, welding smoke, chromium, nickel and the like. The assessment has been designed specifically for integrated tool systems (e.g. tool, dust extractor, extractor hose and dust extractor). This test methodolgy is intended to assess the exposure of employees to hazardous substances compared to the prevailing threshold limit values (TLV 8-hr TWA). An employee's exposure is measured during the working (drilling, sanding, grinding, sawing and so forth) of the building materials calcium silicate, concrete, wood and others. This work is performed in the TNO Worst Case Room, a relatively small workspace (15 m^3).
The tool is tested at 100 % duration of operation. The TNO Worst Case Room is ventilated with 150 m^3/hour (filtered) outside air. This test room has been validated with results gained in actual field situations. The exposure measurements are performed in the employee's breathing zone. The measuring results are tested against the prevailing threshold limit values (TLV 8-hr TWA) of the hazardous substances mentioned above.

2 TNO Worst Case Room

The TNO Worst Case Room is a space measuring 15 m^3, which makes it comparable in size to an actual workspace such as a bathroom.
This test room is typical of an unfavourable working situation (worst case). In furnishing it, TNO has applied two European standards:

- NEN-EN 1093-8 Safety of Machines - Evaluation of the emission of airborne hazardous substances - Part 8: Pollutant Concentration Parameter, test bench method and;
- NEN-EN 1093-9 Safety of Machines - Evaluation of the emission of airborne hazardous substances - Part 9: Pollutant Concentration Parameter, test room method.

The TNO Worst Case Room is part of the EMB Laboratory (see photograph 2). The general specifications of the Worst Case Room (see photograph 1) are as follows:

- dimensions 2.5 by 2.5 by 2.3 metres; volume 15 m^3; volume of ventilation lock 3.5 m^3;
- adjustable (filtered Hi-Flow 80/125-95) air supply 10–250 m^3/hour;
- air quality (pure): less than 0.01 mg respirable dust per m^3;
- adjustable temperature 10–40 degrees Celsius;
- adjustable humidity 20–95 %.

Foto 1. TNO Worst Case Room

Photograph 2. TNO EMB Laboratory

3 Test procedure

The test conditions specific to the test room and the test materials are described in this chapter. The tests are performed under 'standard' conditions in the TNO Worst Case Room (see 3.1). The operations (drilling, grinding, sawing, breaking, and the like) are performed on a number of 'reference' building materials (see 3.2). The employee's exposure is established in his breathing zone while he works the building materials continuously during a measurement period lasting 60 minutes. An (industrial) dust extractor has been placed in the TNO Worst Case Room.

3.1 TNO Worst Case Room specifications.

The exposure tests are performed under the following test room conditions:
- air supply: 150 m³/hour;
- air extraction: 150 m³/hour;
- temperature: 20–25 degrees Celsius;
- relative humidity: 40–60 %.

3.2 Test material specifications.

Four test materials are currently available, i.e. calcium silicate, concrete, hardwood (meranti) and metal. These materials are placed in the TNO Worst Case Room and worked with tools customarily used in the construction industry, the timber industry and the metal industry. The materials are specified in greater detail in the following subsections.

3.2.1 Calcium silicate

Calcium silicate blocks type CVK L100/198. Dimensions (length, height, thickness): 300 mm, 200 mm and 100 mm. The average percentage of respirable quartz in the respirable dust is approx. 25 %. This percentage has been ascertained by TNO using the FTIR analysis technique.

3.2.2 Concrete, brick and keramic tiles

Concrete blocks measuring 600 x 600 x 150 mm are used for the experiments involving the material concrete. As a second material, concrete pavers are used (40 x 60 x 5 cm). Dimensions of ceramic tiles: 300 x 450 x 10 mm.
The average percentage of respirable quartz in the respirable concrete dust is approx. 15 %. This percentage has been ascertained by TNO using the FTIR analysis technique.

3.2.3 Hardwood (Meranti)

Meranti beams measuring 10 x 10 mm or meranti sheet material (9m thick) are used for the experiments involving hardwood.

3.2.4 Metal

The material used in the experiments involving a metal depends on the project concerned. For example, to determine exposure to chromium and nickel, stainless steel (RVS) is welded; to determine hexavalent chromium, metal coated with a chromatic primer is used; to determine welding smoke, unalloyed metal is used.

3.3 Operation– material choice matrix

The table below shows which building materials are used for the drilling, grinding, sawing, and so on.

Table 1. Overview of operations in relation to building materials.

Operations	**Reference building materials**
Stony materials	
Drilling (rotary hammer < 3 kg) Drilling diameter 12 mm, drilling depth 80 mm	Concrete block: 600x600x150 mm (l x w x h)
Drilling (rotary hammer > 3 kg) Drilling diameter 300 mm, drilling depth 80 mm	Concrete block: 600x600x150 mm (l x w x h)
Drilling (wet): 10 – 350 mm, depth 80 mm	Concrete block: 600x600x150 mm (l x w x h)
Sanding/polishing	Concrete pavers: 500x500x50 mm (l x w x h)
Grinding (right-angle grinder)	Calcium silicate bricks: 430x300x70 mm (l x w x h)
Wall chaser	Calcium silicate bricks: 430x300x70 mm (l x w x h)
Breaking/demolishing (dry)	Concrete block: 600x600x150 mm (l x w x h)
Grinding	Ceramic tiles: 450x300x10 mm (l x w x h)
Grinding (wet)	Concrete block: 1000x600x150 mm (l x w x h)
Breaking/demolishing (wet)	Concrete block: 600x100x250 mm (l x w x h)
Sawing (dry)	Calcium silicate/Brick 200x100x50 mm (l x w x h)
Sawing (wet)	Calcium silicate/Brick 200x100x50 mm (l x w x h)
Wood	
Drilling drilling diameter 12 mm, drilling depth 80 mm	Meranti: 1250x210x80 mm (l x w x h)
Sanding (grit size P100)	Meranti: 1250x210x80 mm (l x w x h)
Sawing (diameter < 200 mm); fine pitch Z50	Hardwood multiplex 9 mm thickness
Sawing (diameter > 200 mm); fine pitch Z50	Meranti: 1250x155x33 mm (l x w x h)
Sawing (diameter > 300 mm); fine pitch Z50	Meranti: 1250x620x33 mm (l x w x h)
Jigsawing; fine pitch	Hardwood multiplex 9 mm thickness
Moulding (diameter 12 mm, depth 80 mm)	Meranti: 1250x210x80 mm (l x w x h)

Table 2. Overview of source strengths for different operations

Werkzaamheden	**Referentie bronsterkte per 8-urige werkdag**
Stony materials	
Drilling (rotary hammer < 3 kg): drilling diameter 12 mm; drilling depth 80 mm	2000 drilling holes (100 % duration of operation)
Drilling (rotary hammer > 3 kg): drilling diameter 30 mm; drilling depth 80 mm	1000 boorgaten (100 % duration of operation)
Drilling (wet) drilling diameter 10 mm; drilling depth 80 mm	500 drilling holes (100 % duration of operation)
Drilling (wet) drilling diameter 350 mm; drilling depth 80 mm	50 drilling holes (100 % duration of operation)
Sanding/posishing	100 % duration of operation
Grinding (angle grinder)	500 meter single grinding slot (2 mm x 25 mm) (100 % duration of operation)
Wall chaser	500 meter double slot (2 mm x 25 mm) (100 % duration of operation)
Grinding ceramic tiles	50 meter single grinding slot (100 % duration of operation, reduced)
Grinding (wet) concrete block	100 meter single grinding slot (100 % duration of operation)
Breaking/demolishing (dry)	100 % duration of operation
Breaking/demolishing (wet)	100 % duration of operation
Sawing (dry)	100 % duration of operation
Sawing (wet)	100 % duration of operation
Wood	
Drilling drilling diameter 12 mm, drilling depth 70 mm	2000 drilling holes (100 % duration of operation)
Sanding (grit size P100)	100 % duration of operation
Sawing (diameter < 200 mm); fine pitch Z50	500 meter (hardwood multiplex 9 mm thickness) (100 % duration of operation)
Sawing (diameter > 200 mm); fine pitch Z50	250 meter (meranti 33 mm thickness) (100 % duration of operation)
Sawing (diameter > 300 mm); fine pitch Z60	700 meter (meranti 33 mm thickness) (100 % duration of operation)
Jigsaw (fine pitch)	500 meter (hardwood multiplex 9 mm thickness) 100 % duration of operation
Moulding (diameter 12 mm, depth 80 mm)	4000 moulding holes (100 % duration of operation)

The material to be worked is placed in the TNO Worst Case Room. The tool, a hand tool or otherwise, and its control measure (dust extractor, water, steam) is also placed in the test room. The work situation is outlined in Figure 3.

Figure 3. Diagram of the TNO test set-up

The air treatment system is switched on. After 30 minutes of stabilising the Worst Case Room, the exposure tests can begin.

The tool is used continuously (duration of operation 100%) on the material in question for a period of 60 minutes. The tools with control systems are used in accordance with the instructions in the manual(s) produced by the manufacturer(s)/supplier(s). If applicable, the tool is set to maximum specifications (maximum power, speed, impact force and so on). After 60 minutes the experiment is stopped.

3.4 Test procedure for dust extractors

A number of types of dust extractor can be distinguished. These are listed below. The filter cleaning protocol that is followed during the TNO tests is stated subsequently.

- Dust extractors with **automatic cleaning** based on **vibrations**;
- Dust extractors with **automatic cleaning** based on **air reversal**;
- Dust extractors with **semi-automatic cleaning** based on **vibrations**. Semi-automatic means that when the flow indication lamp (red) is illuminated, cleaning is automatically activated at the next stop-start (pause) provided the tool is switched on and off via the dust extractor (AR setting);
- Three-step filter system (cyclonic, particulate filter, HEPA filter) with **manual cleaning;**
- Dust extractors with an integrated filter-dust capture bag.

Dust extractors with an automatic filter cleaning system are considered preferable. A cleaning system based on vibrations is considered preferable to a system using air reversal. With air reversal, the filter is cleaned by air pulses, which exerts overpressure on the dust extractor. This introduces the possibility that dust from the dust extractor will leak into the employee's work environment through the seals (gaskets).

Semi-automatic cleaning (vibrations) is less effective and imposes requirements on the user. Often the necessity to clean is indicated by a (red) lamp or an acoustic signal. In practice, the employee will not always notice these signals (e.g. the noise of the tool and the dust extractor may drown out the signal) and the necessary steps won't be taken at the right time.

As things currently stand, when any three-step filter system is used, manual cleaning is required. This imposes requirements on the employee. The use of a cyclone as a pre-separator will slow down the speed at which the particulate filters and HEPA filters become clogged and the rate at which these dust extractors lose suction capacity.

When the TNO tests are performed, the following cleaning procedures are applied:

1. **Automatic cleaning** switched on. The capacity of the dust extractor is measured with an ACIN FlowFinder before and after the measuring period (1 hour) once the filters have been cleaned.
2. **Semi-automatic cleaning** switched on (AR setting or equivalent). The tool (right-angle grinder or other tool) is connected electrically with the dust extractor. When the right-angle grinder is switched off, the cleaning system is automatically activated. When the red light is “on” the right-angle grinder is switched off, thereby activating the cleaning system.
   The capacity of the dust extractor is measured with an ACIN FlowFinder before and after the measuring period (1 hour) once the filters have been cleaned.
3. Manual cleaning is performed every 15 minutes. This means cleaning takes place four times per 60 minutes. The capacity of the dust extractor is measured with an ACIN FlowFinder before and after the measuring period (1 hour) once the filters have been cleaned.
4. For dust extractors with an integrated filter-dust capture system (Numatic-Airbo) the need to insert a new filter-dust capture bag is signalled. The capacity of the dust extractor is measured with an ACIN FlowFinder before and after the measuring period (1 hour).

4 Measuring methodologies

For each experiment, dust samples of the hazardous substance are collected at three sites.
In the employee's breathing zone:
- on the employee's left lapel;
- in the centre of the employee's lapel;
- on the employee's right lapel.

Particular measuring systems are used to collect the samples. This information is presented in Table 2 below.

Table 3. Overview of measuring equipment and analysis techniques

Material	**Type of sampling head**	**Pump type**	**Filter**	**Analysis technique**
Calcium silicate/ concrete/ brick	FSP 10 cyclone	Giliam AirCon2 (10 dm^3/min)	Glass fibre 37 mm	Gravimetry (respirable dust - quartz)
Calcium silicate/ concrete/ brick	FSP 10 cyclone	Giliam AirCon2 (10 dm^3/min)	MCE 37 mm	FTIR (respirable quartz)
Ceramic tiles	FSP 10 cyclone	Giliam AirCon2 (10 dm^3/min)	Glass fibre 37 mm	Gravimetry (respirable dust - quartz)
Ceramic tiles	FSP 10 cyclone	Giliam AirCon2 (10 dm^3/min)	MCE 37 mm	FTIR (respirable quartz)
Hardwood	PAS 25 mm (open)	Giliam AirCon2 (10 dm^3/min)	Glass fibre 25 mm	Gravimetry (inhalable sawdust)
Welding smoke	PAS 25 mm (open)	Giliam AirCon2 (10 dm^3/min)	Glass fibre 25 mm	Gravimetry (welding smoke)
Metal (coated with strontium chromate primer)	PAS 25 mm (open)	Giliam AirCon2 (10 dm^3/min)	PVC 25 mm	Spectrometry (hexavalent chromium)

5 Analyses

5.1 Detection limits for respirable quartz (TLV 8-hr TWA: 0.075 mg/m^3)

Detection limit using gravimetric determination on 37 mm glass fibre filter: 0.05 mg dust (absolute).
Therefore the detection limit for a 60-minute sampling period and sampling flow rate of 10 dm^3/min and a quartz percentage of 25 % is: **0.021 mg/m^3**
Therefore the detection limit for a 60-minute sampling period and sampling flow rate of 10 dm^3/min and a quartz percentage of 15 % is: **0.013 mg/m^3**

Quick scan of respirable quartz using FTIR
Detection limit using FTIR determination on 37 mm MCE filter: 1 µg respirable quartz (absolute).
Therefore the detection limit for a 60-minute sampling period and sampling flow rate of 10 dm^3/min and a quartz percentage of 25 % is: 2 **µg/m^3**

5.2 Inhalable sawdust (hardwood) (TLV 8-hr TWA: 2 mg/m^3)

Detection limit using gravimetric determination on 25 mm glass fibre filter in open filterholder: 0.05 mg dust (absolute).
Therefore the detection limit for a 60-minute sampling period and sampling flow rate of 10 dm^3/min is: **0.08 mg/m^3** (TLV 8-hr TWA is 2 mg/m^3).

5.3 Hexavalent chromium (TLV 15-min TWA: 10 µg/m^3)

Detection limit using gravimetric determination on 25 mm PVC filter in open filterholder:
0.1 µg hexavalent chromium (absolute).
Therefore the detection limit for a 60-minute sampling period and sampling flow rate of 10 dm^3/min is: **0.17 µg/m^3**

5.4 Welding smoke (TLV 8-hr TWA: 1 mg/m^3)

Detection limit using gravimetric determination on 25 mm glass fibre filter in open filterholder: 0.05 mg welding smoke (absolute).
Therefore the detection limit for a 60-minute sampling period and sampling flow rate of 10 dm^3/min is: **0.08 mg/m^3**

6 TNO label

The measuring results obtained in the TNO Worst Case Room are tested against the current Threshold Limit Values for chemical substances in the work environment (TLV). The following threshold limit values are applied:

- Respirable quartz: TLV 8-hr TWA: 0.075 mg/m^3;
- Sawdust (hardwood): TLV 8-hr TWA: 2,0 mg/m^3;
- Hexavalent chromium: TLV 8-hr TWA: 10 µg/m^3;
- Welding smoke: TLV 8-hr TWA: 1.0 mg/m^3.

Figure 4 below shows two examples of the TNO labels. Eight labels are available, ranging from one to eight hours. As this suggests, a responsible duration of operation per 8-hour work day can vary from one to eight hours.

The one-hour label means that the tool system can be used for one hour per day (provided the one hour is divided evenly over the 8-hour work day) without exceeding the threshold limit value for the hazardous substance in question (e.g. respirable quartz). The ultimate label is of course the 8-hour label; this tool can be used all day (100 % duration of operation) without exceeding the relevant threshold limit value.

Figure 4. TNO labels for 1 hour and 8 hours.

The label is calculated as follows: **(TLV/ exposure) x 8 hours**
Whereby:

TLV= threshold limit value that applies to the substance (mg/m^3)
exposure = measured exposure in employee's breathing zone (mg/m^3)
8 hours = eight-hour work day

The label is rounded off to a whole number (1-8). If the measured value is less than one, no label is assigned to the tool system concerned.
'Measurement inaccuracy' is approx.15 % (5% analysis; 5 % sampling and 5 % user reproducibility). This means that the assigned label carries a possible 'inacuracy' (including rounding off) of at most one hour.

Example: The result of measurement is a label of 1.4. With a measurement inaccuracy of 15 % this means a range of 1.2–1.6…and therefore, after rounding off, a label of 1 or 2, assuming the same measured average.

7 Reports

For the reports, please go to the TNO website at www.stofvrijwerken.tno.nl
Among the documents available on the website are:

- the TNO Newsletter;
- the TNO Performance Test;
- the TNO Classification of Dust Extractors.

The TNO website and an example of the TNO Newsletter are shown below in Figures 5 and 6.

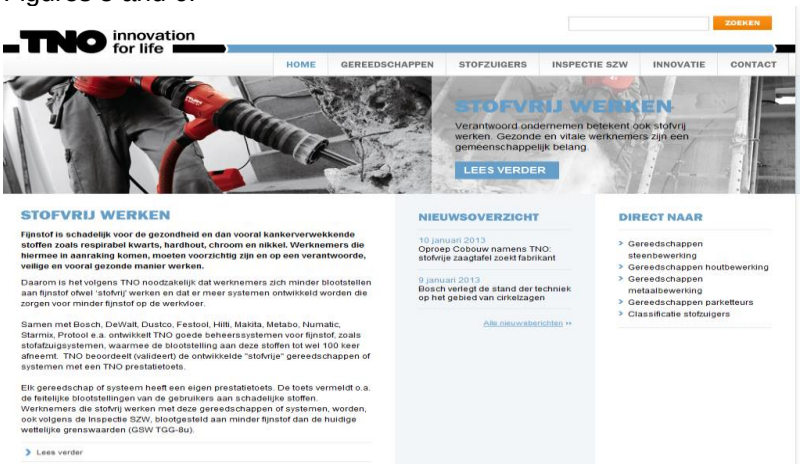

Figure 5. Front page of TNO website www.stofvrijwerken.tno.nl

Figure 6. TNO Newsletter