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Final report

Comparison of dust emissions when using various 3M fibre discs and grinding wheels

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SUMMARY

In this comparative study[1], dust measurements performed while machining with an angle grinder were used to make a comparison between the dust emissions of 3M Cubitron™II grinding wheels and fibre discs and classic grinding wheels and fibre discs[2] for two types of materials to be machined, namely stainless steel SS304L (SS) and ST37 (Steel).

The Cubitron™II discs always scored better than their reference discs in terms of the quantity of dust emitted per quantity of plate material removed. For the various comparisons, this difference was between 30 and 50%. The difference was observed both for the coarser and the finer dust fractions.

Finally, the operating speed and wear of the discs were also determined in these tests. The tested Cubitron™II discs also operated faster and had a lower wear rate.

[1] The results obtained in this study are based on specific conditions described in the test setup; the tests may yield other results in other conditions.

[2] Cubitron™II discs are products in which "3M Precision Shaped Grain Technology" is applied. "Classic" discs are discs that contain "crushed mineral".

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CHAPTER 1. INTRODUCTION

1.1. INTRODUCTION

The aim of this comparative study is to compare dust measurements performed while machining with an angle grinder. This to make a comparison between the dust emissions of 3M Cubitron™II grinding wheels and fibre discs versus classic grinding wheels and fibre discs[3] for two types of materials to be machined, namely stainless steel SS304L (SS) and ST37 (Steel). Each time the machining is performed with the same angle grinder.

1.2. FRAMEWORK OF STANDARDS AND RELEVANT TERMS

1.2.1. RELEVANT TERMINOLOGY AND STANDARDS

The terminology for particle size distributions in this study follows the general terminology in accordance with ISO 7708:1995 Air quality -- Particle size fraction definitions for health-related sampling and European standard EN 481:1993 Size fraction definitions for measurement of airborne particles.
The most relevant terms in connection with this study are:

- Inhalable dust: all dust particles with an (aerodynamic[4]) diameter of less than 100 µm.
- Respirable dust: sub-fraction of inhalable dust, covering all particles with an (aerodynamic) diameter of less than 4 µm. The term 'lung-accessible' is sometimes also used for this fraction.

(Apart from composition) the harmfulness of particles depends on the size distribution of the dust. Larger particles have more chance of being deposited in the oral cavity or the upper airways. Smaller particles, on the other hand, can penetrate further/deeper into the more sensitive part of the lung tissue.
This principle is shown in figure 1. Apart from the inhalable fraction and the respirable fraction, consisting of particles of less than 4µm, the figure also shows the thoracic fraction (<10 µm).

[3] Cubitron™II discs are products in which "3M Precision Shaped Grain Technology" is applied. "Classic" discs are discs that contain "crushed mineral".
[4] Particles (such as fine dust) usually have irregular shapes, which makes it difficult to determine their exact size. The aerodynamic diameter denotes the size of a perfectly spherical particle with unity density (1 g/cm3) that precipitates with exactly the same final speed as the studied particle.

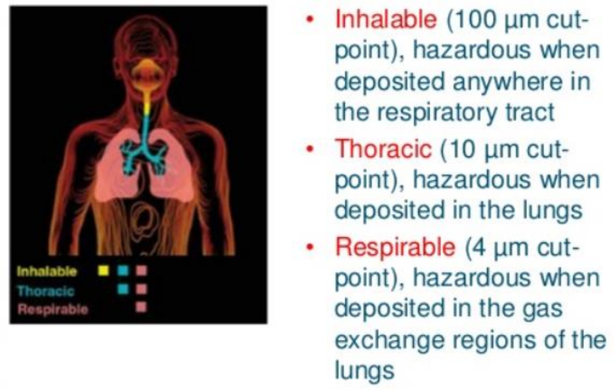


Figure 1: Locations in the respiratory system where particles of a certain size are mainly deposited.

The methods mostly used to sample fine dust in work locations are described in “EN 13205 Workplace atmospheres - Assessment of performance of instruments for measurement of airborne particle concentrations” or in “NIOSH NMAM 0500 Particulates not otherwise regulated, total”.
The method used for these tests differs (see further down), but the end results are comparable.

1.2.2. Health effects of fine dust[5]

Aerosol particles are known to be the ideal means of transport for bringing a number of toxic components into the lungs. Depending on their size, the dust particles are deposited in the nasal cavity, pharynx and oral cavity, lungs or the alveoli. The smaller particles penetrate deepest into the lungs. PM10 dust can disrupt the removal of mucus in the airways due to its mechanical and toxic effects, trigger breathing problems and increase the sensitivity to airway infections. Among other things, the presence of polycyclic aromatic hydrocarbons (PAHs) and carcinogenic metals in certain dust particles can promote the development of lung cancer. After being deposited in the lungs, other toxic components of dust can spread even further into the (human) body via the bloodstream or the lymphatic system. Ultrafine particles can penetrate the bloodstream relatively quickly after respiration (Nemmar et al., 2002). The ultrafine character of particles increases the toxicity of fine dust and (partially) explains the health effects (Macnee & Donaldson, 1999; Donaldson & Stone, 2003). There are also signs that the ultrafine character of the particles increases the toxicity, among other things, based on experiments with the inert substances TiO2 and graphite particles (Donaldson & Stone, 2003).
These were administered to people both in fine, respirable form and in ultrafine form, and the response was clearly different. Both PM10, PM2.5 and even finer particles (PM0.1) can trigger inflammation mechanisms in the lungs. However, the contact area increases as the particles become finer. A larger surface area increases the chances of toxic, carcinogenic, allergenic, etc. components reacting with lung cells on this surface.

Both the mass quantity and the number of particles being absorbed through respiration determine the toxicity. Coarse dust is mainly absorbed by the body via the digestive tract, but it also contains

[5] Extract from the Flanders Environmental Report by the Flemish government: Background document can be accessed on:
http://www.milieurapport.be/nl/feitencijfers/milieuthemas/luchtkwaliteit-verspreiding-van-fijn-stof/

a number of toxic metals. Attention is shifting more and more towards PM2.5 and PM0.1, but scientists do point out that the coarser PM10 fraction should not be forgotten.

CHAPTER 2. DESCRIPTION OF THE TESTS

To compare the dust emissions when machining (stainless) steel using fibre discs or grinding wheels, no standard protocol could be found. This is why a protocol was specified independently as part of this study.

5 different 3M fibre discs and grinding wheels were tested on 2 different materials: stainless steel SS304L (SS) and ST37 (steel).

The various combinations of materials and discs are presented below:

Material	Disc code	disc type
SS	2	Cubitron™ 985C fibre disc
SS	5	Cubitron™II 987 SS fibre disc
SS	4	HP steel grinding wheel
SS	3	Cubitron™II grinding wheel
Steel	2	Cubitron™ 985C fibre disc
Steel	1	Cubitron™II 982C steel fibre disc
Steel	4	HP steel grinding wheel
Steel	3	Cubitron™II grinding wheel

The full test protocol is described in annex.

CHAPTER 3. RESULTS

For each test, the number of grams of dust mass emitted per gram of plate material removed is determined for the individual test results per disc/material combination. These results are presented in table 1.
For each test pair of Cubitron™II disc and reference disc, the difference in emitted dust can be determined. This comparison is determined per day and the average over the various days is then calculated.

Table 1: Overview of the results of the various tests

Material		disc type	dust mass of fine dust in grams per gram of material removed (inhalable fraction)			% drop in dust emission for Cubitron™ II v classic discs			
			day 1	day 2	day 3	day 1	day 2	day 3	average
SS	2	Cubitron™ 985C fibre disc	0.0100	0.0083	0.0095				
SS	5	Cubitron™II 987 SS fibre disc	0.0065	0.0050	0.0075	35%	40%	21%	32%
SS	4	HP steel grinding wheel	0.0146	0.0125	0.0108				
SS	3	Cubitron™II grinding wheel	0.0086	0.0053	0.0064	42%	58%	41%	47%
Steel	2	Cubitron™ 985C fibre disc	0.0065	0.0056	0.0082				
Steel	1	Cubitron™II 982C steel fibre disc	0.0031	0.0037	0.0035	52%	34%	57%	48%
Steel	4	HP steel grinding wheel	0.0110	0.0117	0.0122				
Steel	3	Cubitron™II grinding wheel	0.0063	0.0064	0.0084	43%	45%	31%	40%

The last column of the table shows that the Cubitron™II type discs release between 30 and 50% less inhalable dust per gram of material removed in comparison with the classic discs.

Comment regarding reliability of the tests by an experienced 3M operator:
As no standard test protocol was available, VITO drew up a protocol itself. As this protocol is best performed by an experienced operator, VITO asked 3M to have the first 2 test days performed by an experienced 3M operator. To maintain control of the objectivity and independence of the tests, however, the tests during the 3rd day were performed by a VITO operator. The test protocol included a number of checks to ensure that the results were not preferentially influenced.
These checks were performed by comparing the results of the 3rd day with the results of the first 2 days.
The following observations were made here:

- In 4 out of the 8 cases, the VITO lab assistant obtained the highest measurement out of the 3 days, the lowest in 1 case.
- 2 out of the 4 highest values measured during machining by the VITO operator came from the classic discs and 2 came from the Cubitron™II discs.

No systematic deviation between the first 2 days and the final day could be found, which could indicate that the tests were influenced, with the Cubitron™II discs benefiting during the first 2 days. As a result, the tests are considered to be reliable and not manipulated in a particular direction.

3.1. STATISTICAL ASSESSMENT

To test whether the difference between the various types of discs is also statistically significant, the statistical Student's t-test is used[6]. This test indicates whether the average values of 2 series differ with sufficient confidence ($p < 0.05$ = more than 95% confidence).

table 2 shows that the differences between the discs are indeed statistically significant.

Table 2: Statistical assessment of the results

Material		disc type	dust mass of fine dust in grams per gram of material removed (inhalable fraction)			p-value of t-test*
			day 1	day 2	day 3	
SS	2	Cubitron™ 985C fibre disc	0.0100	0.0083	0.0095	**0.03**
SS	5	Cubitron™II 987 SS fibre disc	0.0065	0.0050	0.0075	
SS	4	HP steel grinding wheel	0.0146	0.0125	0.0108	**0.02**
SS	3	Cubitron™II grinding wheel	0.0086	0.0053	0.0064	
Steel	2	Cubitron™ 985C fibre disc	0.0065	0.0056	0.0082	**0.04**
Steel	1	Cubitron™II 982C steel fibre disc	0.0031	0.0037	0.0035	
Steel	4	HP steel grinding wheel	0.0110	0.0117	0.0122	**0.01**
Steel	3	Cubitron™II grinding wheel	0.0063	0.0064	0.0084	

* 2-tailed Student's t-test with unequal variances.

[6] https://en.wikipedia.org/wiki/Student%27s_t-test#Paired_samples And the reference that this test may also be used for such a small random sample (#3): http://www.pareonline.net/pdf/v18n10.pdf

3.2. SIZE DISTRIBUTION OF THE EMITTED DUST

One of the objectives of the project was to determine whether the dust being released with the various disc/material combinations had a different size distribution.
Table 3 presents the relative distribution of the dust for the various disc/material combinations. These results are averages of the separate tests performed on the 3 different days. This table shows that mainly the disc type (fibre disc v grinding wheel) has an effect on the size distribution of the dust.

Seeing that the Cubitron™II disc releases less inhalable dust per gram of material removed than the classic discs, fewer of the finer dust fractions are therefore also released. The reduction percentage of the dust emissions is also 30 to 50% for the finer fractions.

Table 3: % distribution for the various dust fractions in the various tests

			%PM1	%PM4 Respirable fraction	%PM10	Inhalable fraction
			compared to inhalable fraction			(%)
SS	2	Cubitron™ 985C fibre disc	1.5	16	55	100
SS	5	Cubitron™II 987 SS fibre disc	1.8	17	54	100
SS	4	HP steel grinding wheel	3.0	30	76	100
SS	3	Cubitron™II grinding wheel	2.6	30	78	100
Steel	2	Cubitron™ 985C fibre disc	2.4	17	49	100
Steel	1	Cubitron™II 982C steel fibre disc	2.8	14	41	100
Steel	4	HP steel grinding wheel	5.8	24	62	100
Steel	3	Cubitron™II grinding wheel	4.8	28	69	100

3.3. LOSS OF MATERIAL FROM THE PLATE AND WEAR OF THE DISCS

The loss of material from the plate and the weight loss of the discs were also determined during the tests. Table 4 presents the average values of the tests over the 3 different days.
This shows that the Cubitron™II discs can remove more material per unit of time from both the stainless steel plate and from the regular standard steel plate, and that the Cubitron™II discs also lose less material (i.e. have lower wear) during the tests.

Table 4: Loss of material from the plate and weight loss of the disc

			Plate loss of material (g)	Disc weight loss (g)
SS	2	Cubitron™ 985C fibre disc	-105.7	-2.6
SS	5	Cubitron™II 987 SS fibre disc	-136.2	-2.5
SS	4	HP steel grinding wheel	-77.5	-13.0
SS	3	Cubitron™II grinding wheel	-149.8	-7.3
Steel	2	Cubitron™ 985C fibre disc	-212.8	-2.4
Steel	1	Cubitron™II 982C steel fibre disc	-309.3	-1.7
Steel	4	HP steel grinding wheel	-110.9	-10.3
Steel	3	Cubitron™II grinding wheel	-197.2	-7.8

CHAPTER 4. CONCLUSION

During 3 test days, machining tests were carried out with 8 combinations of fibre discs and grinding wheels from 3M.

Material	disc type
SS	Cubitron™ 985C fibre disc
SS	Cubitron™II 987 SS fibre disc
SS	HP steel grinding wheel
SS	Cubitron™II grinding wheel
Steel	Cubitron™ 985C fibre disc
Steel	Cubitron™II 982C steel fibre disc
Steel	HP steel grinding wheel
Steel	Cubitron™II grinding wheel

The Cubitron™II discs always scored better than their reference discs in terms of the quantity of dust emitted per quantity of plate material removed. For the various comparisons, this difference was between 30 and 50%[7].

In addition, it turns out that mainly the disc type (fibre disc v grinding wheel) has an effect on the size distribution of the dust.
Seeing that the Cubitron™II disc releases less inhalable dust per gram of material removed than the classic discs, fewer of the finer dust fractions are therefore also released. The reduction percentage of the dust emissions is also 30 to 50% for the finer fractions.

Additionally, the Cubitron™II discs are faster and more efficient in the sense that they remove more material per unit of time and are less subject to wear.

[7] The results obtained in this study are based on specific conditions described in the test setup; the tests may yield other results in other conditions.

Annex A

Test day 21/12/2015

Test start time	stop time	grinding start	stop	plate type	mass before (g)	mass after (g)	disc type	mass before (g)	mass after (g)	loss of mass (g) Test material	discs	emitted dust (g)	volume sampled (m³)	dust conc. (mg/m³)	dust mass per grams of material
10:24	10:48	10:27:20	10:32:20	SS	11427.5	11317.5	2	32.69	30.24	-110	-2.45	1.10	0.40	2.74	0.0100
10:51	11:22	10:52:40	10:57:40	SS	11317.5	11181.5	5	27.24	24.14	-136	-3.1	0.88	0.52	1.70	0.0065
11:32	12:00	11:32:35	11:38:35	Steel	11230.5	11014	2	32.91	30.26	-216.5	-2.65	1.41	0.47	3.02	0.0065
12:01	13:06	12:03:07	12:08:07	Steel	11014	10678.5	1	29.67	27.78	-335.5	-1.89	1.05	1.09	0.97	0.0031
13:34	13:59	13:36:10	13:41:10	SS	11181.5	11077.5	4	180.8	162.15	-104	-18.65	1.52	0.42	3.64	0.0146
14:00	14:30	14:06:16	14:07:16	SS	11077.5	10898.5	3	200.67	190.26	-179	-10.41	1.53	0.50	3.05	0.0085
14:31	15:06	14:32:37	14:37:37	Steel	10678.5	10579.5	4	181.98	174.12	-99	-7.86	1.09	0.58	1.86	0.0110
15:07	15:59	15:09:17	15:14:17	Steel	10579.5	10392.5	3	200.39	195.61	-187	-4.78	1.17	0.87	1.35	0.0063

SS	2	Cubitron™ 985C fibre disc
SS	5	Cubitron™II 987 SS fibre disc
Steel	2	Cubitron™ 985C fibre disc
Steel	1	Cubitron™II 982C steel fibre disc
SS	4	HP steel grinding wheel
SS	3	Cubitron™II grinding wheel
Steel	4	HP steel grinding wheel
Steel	3	Cubitron™II grinding wheel

Test day 22/12/2015

Test		grinding		plate			disc			loss of mass (g)					dust mass per
start time	stop time	start	stop	type	mass before (g)	mass after (g)	type	mass before (g)	mass after (g)	test material	discs	emitted dust (g)	volume sampled (m³)	dust conc. (mg/m³)	grams of material
10:05	10:31	10:05:30	10:10:30	Steel	11420.5	11270	3	200.28	196.33	-150.5	-3.95	0.97	0.43	2.23	0.0064
10:31	10:54	10:32:00	10:37:00	Steel	11270.5	11184.5	4	180.95	175.35	-86	-5.6	1.01	0.38	2.63	0.0117
10:55	11:22	10:56:00	11:01:00	SS	10899.5	10770	3	200.3	195.4	-129.5	-4.9	0.68	0.46	1.48	0.0053
11:23	11:57	11:24:00	11:29:00	SS	10770	10694.5	4	182.23	169.43	-75.5	-12.8	0.94	0.57	1.64	0.0125
12:00	13:02	12:01:00	12:06:00	Steel	11186	10918	1	29.85	28.46	-268	-1.39	0.99	1.04	0.96	0.0037
13:03	13:32	13:05:00	13:10:00	Steel	10918	10747	2	32.84	30.71	-171	-2.13	0.96	0.48	2.01	0.0056
13:44	14:17	13:45:00	13:50:00	SS	10694.5	10524	5	27.48	24.99	-170.5	-2.49	0.85	0.56	1.53	0.0050
14:19	15:03	14:20:00	14:25:00	SS	10524	10412.5	2	32.55	29.7	-111.5	-2.85	0.92	0.73	1.25	0.0083

Steel	3	Cubitron™II grinding wheel
Steel	4	HP steel grinding wheel
SS	3	Cubitron™II grinding wheel
SS	4	HP steel grinding wheel
Steel	1	Cubitron™II 982C steel fibre disc
Steel	2	Cubitron™ 985C fibre disc
SS	5	Cubitron™II 987 SS fibre disc
SS	2	Cubitron™ 985C fibre disc

Annex A

Test day 07/01/2016

Test		grinding		plat e			disc			loss of mass (g)					dust mass per
start time	stop time	start	stop	type	mass before (g)	mass after (g)	type	mass before (g)	mass after (g)	test material	discs	emitted dust (g)	volume sampled (m^3)	dust conc. (mg/m^3)	grams of material
10:14	10:38	10:17:00	10:22:00	SS	10412.5	10317	2	32.74	30.1	-95.5	-2.64	0.91	0.40	2.27	0.0095
10:41	11:06	10:45:00	10:50:00	SS	10317	10215	5	27.96	25.91	-102	-2.05	0.76	0.42	1.82	0.0075
11:08	11:44	11:11:00	11:16:00	Steel	10393	10142	2	32.61	30.08	-251	-2.53	2.05	0.60	3.41	0.0082
11:45	12:59	11:49:00	11:54:00	Steel	10142	9817.5	1	30	28.17	-324.5	-1.83	1.14	1.24	0.92	0.0035
13:24	13:50	13:28:00	13:33:00	SS	10215	10162	4	180.63	172.98	-53	-7.65	0.57	0.43	1.31	0.0108
13:52	14:19	13:57:00	14:02:00	SS	10162	10021	3	199.75	193.11	-141	-6.64	0.90	0.45	2.00	0.0064
14:22	14:50	14:26:00	14:31:00	Steel	9817.5	9692	4	182.23	169.35	-125.5	-12.88	1.53	0.47	3.27	0.0122
14:51	15:38	14:55:00	15:00:00	Steel	9692	9438	3	199.27	184.61	-254	-14.66	2.13	0.78	2.71	0.0084

SS	2	Cubitron™ 985C fibre disc	
SS	5	Cubitron™II 987 SS fibre disc	
Steel	2	Cubitron™ 985C fibre disc	
Steel	1	Cubitron™II 982C steel fibre disc	
SS	4	HP steel grinding wheel	
SS	3	Cubitron™II grinding wheel	
Steel	4	HP steel grinding wheel	
Steel	3	Cubitron™II grinding wheel	

Test set-up

To compare the dust emissions when machining (stainless) steel using fibre discs or grinding wheels, no standard protocol could be found. This is why a protocol was specified independently as part of this study.

5 different 3M fibre discs and grinding wheels were tested on 2 different materials: stainless steel SS304L (SS) and ST37 (steel).

The various combinations of materials and discs are presented below:

Material	Disc code	disc type
SS	2	Cubitron™ 985C fibre disc
SS	5	Cubitron™II 987 SS fibre disc
SS	4	HP steel grinding wheel
SS	3	Cubitron™II grinding wheel
Steel	2	Cubitron™ 985C fibre disc
Steel	1	Cubitron™II 982C steel fibre disc
Steel	4	HP steel grinding wheel
Steel	3	Cubitron™II grinding wheel

The various tests were performed using the same protocol each time:

- A plate approx. 40 cm wide, 30 cm high and 1 cm thick was clamped in a vice.
- Each time the top edge was ground down at an angle of approx. 45° at a constant pressure for exactly 5 minutes. During this, a sideways motion was carried out and the grinder was moved both to the left and the right during the motion without removing the grinding disc from the plate.

Figure 2: Test setup

To make the tests as reproducible as possible, a number of precautions were taken:

- Before first use, the plate was "prepared" by performing a preliminary test for a few minutes. This ensures that the top section of the plate is ground down at an angle of 45°, so that the results of the first real test would not differ from those of the following tests.
- For each comparative test (= the Cubitron™II disc compared to the classic disc), the same plate is used each time.
- The time between each grinding activity is always more than 30 minutes, to prevent the plate from heating up and exhibiting different mechanical properties as a result.
- The same angle grinder (Metabo) is used each time and a new disc is used for each test.
- During the first 2 test days, the tests were performed by an experienced 3M operator; on the 3rd test day all material/disc combinations were performed by a VITO technician. This incorporates a check to prevent the 3M operator from being able to deliberately or inadvertently influence the test results (more info about this in the results section).
- On day 1 and day 2, the tests were also performed in a different order, to exclude any systematic effects.
- Each time the tests include a comparison between a Cubitron™II disc and a classic disc. The 2 tests required to make 1 comparison were performed in quick succession each time, to minimise any systematic deviations.

4.1. MEASUREMENTS

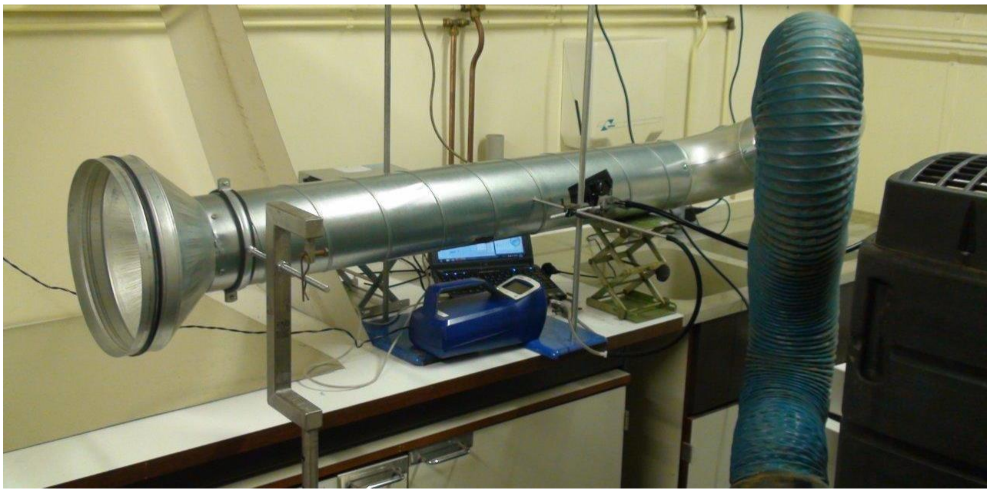
4.1.1. DUST MEASUREMENTS

The tests were performed in a closed room equipped with a local filter ventilation system with a HEPA filter, allowing the dust released to be easily drawn in from the air and filtered during and after each machining run.
The dust concentration of the air being extracted is measured and the filtered air is blown back into the room as clean air. As a result, no air is removed from or added to the room. The actual test time includes both the 5 minutes of the machining and the following minutes required to return the dust concentration in the room to the background level (approx. 0.05 mg/m³).

To measure the dust concentration, a decision was made to use a continuous and stationary measurement in the suction probe of the air filter unit instead of more classic personal sampling of the various dust fractions using devices carried by the operator. This had the following reasons:

- By installing the measuring instruments in the extraction unit, the dust concentration being extracted and circulated can be constantly determined. Taking into account the extraction flow rate, the quantity of dust released and purified can be determined, not just the quantity present in a particular location in the room. The latter would be the case when using personal sampling by the operator.
- A stationary measurement in the room would also be possible for performing comparative tests, but this type of test is more prone to errors, as the air in the room is never the same everywhere and a measuring result would therefore depend on where one happens to be in the room. A measurement in the room does not allow the emitted quantity of dust to be accurately determined either.

To determine the quantity of dust released while machining, 2 measuring instruments were used. Both of them were mounted isoaxially[8] in the extraction system of the air purifier. The various dust fractions were measured using a Grimm 1.108 Dust Monitor. This device reports the dust concentrations in 16 size fractions with a temporal resolution of 6 seconds. These are then used to calculate the inhalable and respirable fractions with a temporal resolution of 1 minute. As this is an optical measuring instrument for which the absolute values of the measurements may deviate from a reference measurement based on a gravimetric/filter method, a Partisol Plus 2025 filter sampler was used as reference. A comparison of the various measurements by the Grimm monitor and the Partisol dust sampler during the 3 days reveals a deviation of 2.9% between both instruments. The results stated in this report have already been corrected for this.
Use of a dust monitor with an immediate read-out has another additional advantage:
Monitoring the dust concentration during the test yields reliable information when the test is finished (= when the dust concentration in the room has dropped sufficiently). Classic personal sampling with a filter that has to be analysed afterwards does not provide any information on when the room is clean enough for a new test, resulting in the risk that a following test could be started before the room is sufficiently clean. This is avoided by using an optical dust monitor.



[8] Isoaxial sampling is done by keeping the inlet of the measuring instrument in the same direction as the air stream in the extraction system.

Figure 3: Setup with suction probe of the air purifier in the room

4.2. CALCULATIONS

For each machining test, the following parameters are determined:

- the dust emission (in different size fractions) is determined using the dust concentration measured in the extraction channel, the extraction flow rate and the time required to purify the room. Once the room is sufficiently clean, all the dust will have been extracted. The dust and the metal chippings that are not extracted (and drop to the floor) are considered too coarse to be part of the inhalable fraction. This partially includes a deviation from the convention in ISO 7708, but this error is judged to be small and, in any case, it is systematic throughout the tests.
- The material removed from the (stainless) steel plate during the machining. Seeing that this serves as a reference point, all the results will refer to this as well. In practice, a particular job will also stop after removing a certain quantity of material (e.g. a welded joint), not after a certain number of minutes.

Wear of the discs. This is not an essential part of the test, which is a comparison of the dust emissions, but it is determined as well for the sake of completeness.