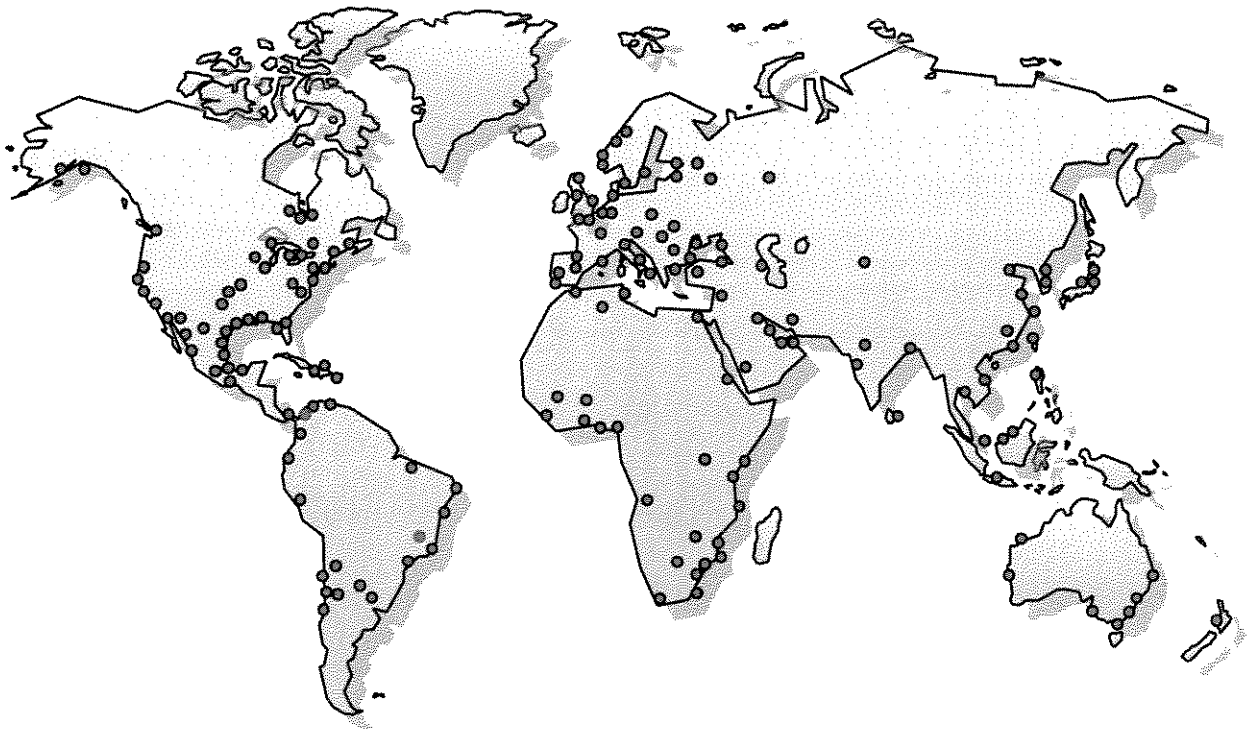
TEST REPORT

REPORT no
Clyo8R0736 PMa/PMa

LABORATORY FUME HOOD
equipped with the filtering system
« GREEN FUME HOOD Technology»



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At the request of : **ERLAB S.A.S.**

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- The present report refers to all the tests performed on the concerned site.

- The report gives the whole test evidences (100 % of raw data, certificates, methods, equipments) that the Customer may exploit his own way.

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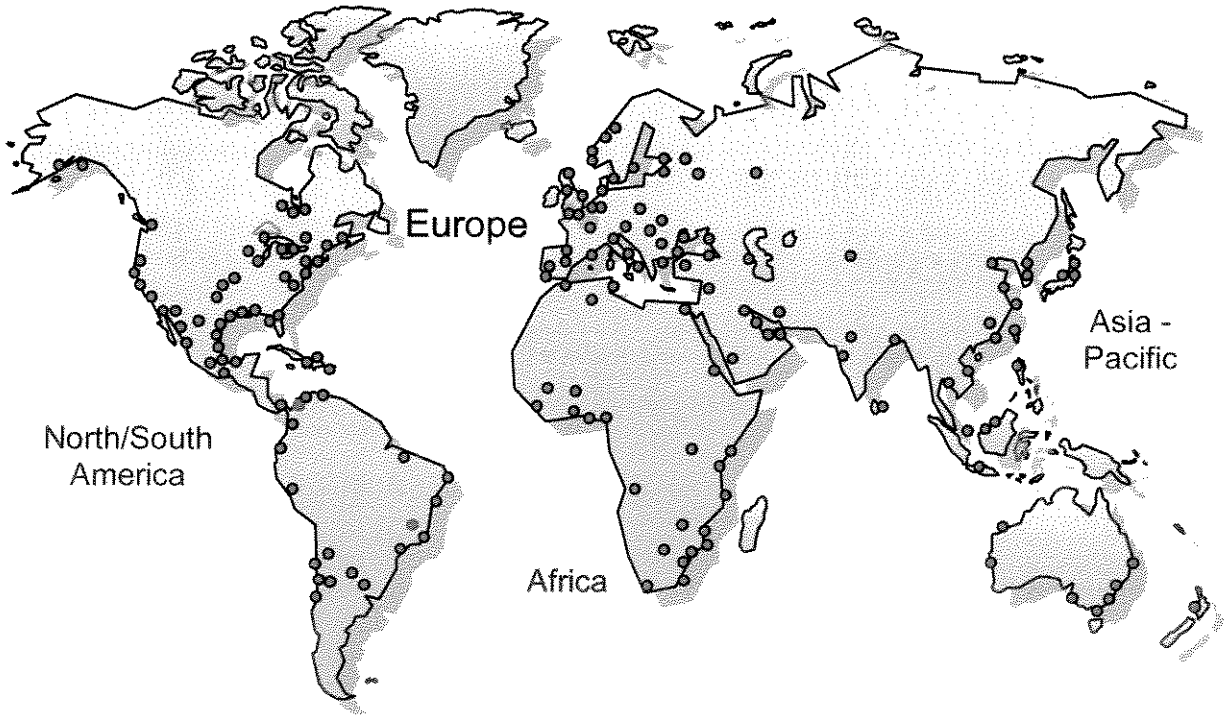

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FOREWORD

At the request of **ERLAB S.A.S.**

following our proposition no **Clyo8P0190 PBo/ATr**

and your order form no **8033**

the tests described in the present report,

were performed at : **R&D Laboratory of ERLAB S.A.S.**
Parc d'Affaires des Portes
Voie du Futur
27104 VAL DE REUIL cedex - France

Tests performed following the procedure provided by the customer, entitled "Efficiency test with acids on a Recirculatory filtration fume cupboard", this procedure being in accordance with the NF X 15-211 standard.

The intervention was performed between September 29th and November 4th, 2008 by :

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This report comprises 198 pages (with annexes).

SYNOPSIS

I. CONCLUSION

The matter of the present study is to guarantee the compliance of a prototype of laboratory fume hood equipped with the filtering system « Green Fume Hood Technology » in accordance with some of the requirements of the NF X 15-211 standard (« the standard ») specifying the classification and the characteristics of the enclosures for toxics with recirculating air filtration.

The test conditions and requirements imposed by NF X 15-211 were respected during the tests. The minor deviations noticed have never been likely to call advantageously into question the test results.

In the conditions imposed by the standard, it was noticed that the enclosure subjected to tests was able to filter 5459 grammes of commercial solution of hydrochloric acid (35.88% w/w) before reaching a reject concentration, downstream of the filtering system, of 1% of the retained Occupational Exposure Limit for this chemical agent (highest concentration imposed by the standard). As two identical and independent filtering modules were parallel installed in the tested enclosure, each filtering module was able to filter 2729 grammes of solution of hydrochloric acid.

If several modules are parallel installed on an enclosure, this filtration value is of course to be multiplied by the number of modules.

Moreover it looks very reasonable to affirm that the safety operating time exceeds $1/12^{th}$ of the normal operating time, as asked by the standard.

Considering these results and the conditions that led to them, the prototype of laboratory fume hood equipped with the filtering system « Green Fume Hood Technology» is fully compliant with the requirements of NF X 15-211 about the filtration efficiency of acid vapors.

However these conclusions must not prejudge the test results that the prototype may obtain in accordance with other requirements of NF X 15-211, particularly the filtration test for volatile organic compounds and the confinement test.

II. PERFORMED TESTS AND OPERATING CONDITIONS

The matter of the present study is to guarantee the compliance of a prototype of laboratory fume hood equipped with the filtering system « Green Fume Hood Technology» in accordance with some of the requirements of the NF X 15-211 standard specifying the classification and the characteristics of the enclosures for toxics with recirculating air filtration.

According to the criteria given in paragraph 4 of this standard, the tested fume hood is an enclosure with safety reserve (class 1) with type V filters (vapors filtration).

The present report refers to the test results for the 5.4 requirement of the standard (« Filtration »), without prejudging the test results that the prototype may obtain in accordance with other requirements of the standard.

The matter of the 5.4 requirement is to assess the filtration performance of the fume hood under precise operating conditions. Indeed the filtering system of a class 1 enclosure with recirculating air filtration shall prevent the rejected air, downstream of the filtering system, from exceeding a concentration of chemical agent of :

- 1 % of the occupational exposure limit (OEL) during the normal operating time
- 50 % of the occupational exposure limit (OEL) during the safety operating time

Moreover the safety operating time shall exceed $1/12^{th}$ of the normal operating time. The terms « normal operating time » and « safety operating time » are defined in the paragraph 3 of the standard.

The 5.4 requirement of the standard prescribes different filtration tests to be performed depending on the filters installed :

- in the case of filters for volatile organic compounds : two successive tests, one with isopropanol, the other with cyclohexane ; each test shall be performed with a new filter.
- in the case of filters for acid vapors : one test with hydrochloric acid.

The customer produces a universal filtering system, supposed to filter both volatile organic compounds and acid vapors. That is why the three tests (isopropanol, cyclohexane, hydrochloric acid) shall be performed with the same model of filtering module. Moreover the produced enclosure has such a width that two identical and independent filtering modules are installed. In particular the air aspiration systems are independent for each module. That is why the retained amounts of chemical agents will have to be divided by two to get the efficiency of one filtering module. These values will then have to be multiplied by the number of filtering modules installed on any enclosure (up to five according to the customer). On the other hand, the different operating times (normal, safety) are obviously independent from the number of filtering modules, as long as this number remains proportional to the internal volume of the enclosure.

The OEL adopted by the standard for these three chemical agents are :

- isopropanol : 400 ppm
- cyclohexane : 300 ppm
- hydrochloric acid : 5 ppm

The test method consists of evaporating a constant and known concentration of a chemical agent in the enclosure functioning its normal way and to regularly analyze the air at the exhaust point downstream of the filtering system. The test shall be performed during 8-hour-runs between which 16 hours are waited if ever several runs are necessary. The concentrations to be evaporated in the enclosure are :

- isopropanol : 200 ppm
- cyclohexane : 200 ppm
- hydrochloric acid : 50 ppm

The present document makes a report only for the results obtained for the « hydrochloric acid » test as the « isopropanol » and « cyclohexane » tests have already been the object of a previous report no Clyo8R0366 PMa/PMa dated August 8th, 2008.

A. NORMATIVE OPERATING CONDITIONS

1. Temperature and relative humidity

The tests shall be performed at 20±2°C and with a relative humidity between 40% and 70%. The heating unit shall not increase the internal temperature of the enclosure by more than 5°C over the temperature in the closed test volume.

2. Closed test volume

The enclosure shall be set in a closed test volume (« bubble »). The internal volume of the bubble shall be between 10 and 50 times the internal volume of the enclosure.

3. Chemical agent evaporation

The chemical agent shall be introduced with a peristaltic pump, drop by drop into a heated container set at the middle of the working bench of the enclosure. During the whole test, the system shall be set so as to generate the desired concentration in the enclosure, with a ± 10% tolerance, for the duration of the test.

4. Air sampling

Air samples shall be taken in three areas :

- « entry » area, 30 cm upstream from the filtering system (in the enclosure)
- « exit » area, 30 cm downstream from the filtering system
- « respiratory tracts » area, in front of the enclosure, level with the respiratory tracts of a person

The standard makes it clear that the sampling method shall prevent the deterioration of the air samples between the sampling area and the analyzer. Moreover a sampling representative of the analyzed air shall be set, for example with multipoint sampling grids.

5. Analyzer

The standard recommends for the analysis of acid vapors the trapping of a known volume of the air to be sampled through a bubbler filled with a $Na_2CO_3/NaHCO_3$ buffer solution. This sample shall then be analyzed with an Ionic Chromatograph.

The standard makes it clear that any other equivalent method can be used.

B. TEST OPERATING CONDITIONS

1. Temperature and relative humidity

A thermo-hygrometer is set inside the enclosure, another thermo-hygrometer is set in the bubble outside the enclosure. Recording of :

- temperature and relative humidity inside the enclosure, and
- temperature outside the enclosure

is allowed every minute by a wireless connection to an acquisition software.

Temperature and relative humidity raw data are attached to the present report.

	Relative Humidity inside the enclosure (%) min/max	Temperature inside the enclosure (°C) min/max	Temperature outside the enclosure (°C) min/max	Max temperature difference between inside and outside the enclosure (°C)
1st day	43.9/53.8	23.0/29.3	23.4/27.4	2.1
2nd day	43.9/52.4	22.5/29.7	22.0/27.8	2.0
3rd day	49.7/57.4	21.8/30.0	21.3/27.6	2.5
4th day	46.2/53.9	18.9/27.6	18.0/25.4	2.3
5th day	46.1/53.5	21.3/28.5	21.2/26.4	2.2
6th day	43.5/52.4	21.0/29.6	21.0/26.8	2.8
7th day	41.4/51.6	21.6/28.4	21.3/26.3	2.2
8th day	41.9/52.4	21.0/28.5	20.7/26.4	2.3

The relative humidity remains inside the acceptance criteria.

The temperature difference between inside and outside the enclosure remains inside the acceptance criteria.

The test temperatures (inside and outside) both regularly exceed the acceptance criteria of the standard (20°C ± 2°C). However numerous references[1] have shown that a higher temperature makes easier the desorption of chemical agents and therefore is detrimental to the filtration efficiency. Therefore this deviation from the standard is not likely to call advantageously into question the test results.

2. Closed test volume

The bubble is a cube with internal dimensions 196 cm by 136 cm by 227 cm, that is to say a volume of 6.05 m^3.

The enclosure is trapezoid-shaped with dimensions 95 cm by 87 cm at the bottom, 75 cm by 87 cm at the top, and 110 cm high, that is to say a volume of 0.81 m^3.

The volume of the bubble is lower than 10 times the volume of the enclosure. That deviates from the acceptance criteria of the standard. However this 25% lower volume

[1] LE CLOIREL, Les composés organiques volatils (COV) dans l'environnement, Tec&Doc Ed., 1998, 454455

obviously involves an unfavorable concentration effect in the bubble. Therefore this deviation from the standard is not likely to call advantageously into question the test results.

3. Chemical agent evaporation

The chemical agent is introduced with a peristaltic pump Heidolph Pumpdrive 5001, drop by drop into a ceramic vessel heated by a hot plate Stuart SB160 set at the middle of the working bench of the enclosure. The vessel contains some pumice stone grains to improve the diffusion and evaporation of the chemical agent. The temperature is set as to instantly evaporate the chemical agent (about 250°C).

A flask containing the chemical agent lies on the plate of a laboratory balance (0,1 g precision). The flask is hermetically closed. A Viton tube goes through the cap and is set on the wheels of the peristaltic pump, as to pump the chemical agent with a constant flow. In order to make up for the loss of volume in the flask, the cap is also pierced by a thin needle, allowing some air to enter. In order to prevent any air pollution in the bubble by evaporation of the chemical agent through this needle, this one is surmounted by a glass syringe body full of activated carbon.

The balance is linked to a dedicated acquisition software BALINT V4.00, recording the decreasing weight every minute.

The pump flow is manually set as to get the desired mass flow (calculated by weight difference in 1 minute). The mass flow m (in g/min) is calculated as a function of the extract volume flow rate Q (in m^3/h), the desired concentration of chemical agent in the enclosure C (in ppm) and the molar weight of the chemical agent M (in g/mol), by the following formula :

$$m\,(g/min) = \frac{Q\,(m^3/h) \times C\,(ppm) \times M\,(g/mol)}{1344000 \times 0.3588}$$

This formula gives the mass flow of commercial solution of hydrochloric acid, as this acid is usually sold as 36-38% (w/w) aqueous solutions. The bottles used for this test were all from the same supplier and the same lot number, which assay is given 35.88% by the supplier.

The extract volume flow rate Q is first calculated as a function of the surface of the sash opening S (in m^2) and the mean air face velocity V (in m/s), measured with an anemometer following the 5.2 paragraph of the NF EN 14175-3:2003 standard, by the following formula :

$$Q\,(m^3/h) = V\,(m/s) \times S\,(m^2) \times 3600$$

The anemometer is set in the plane of sash, its axis being perpendicular to the plane. As a precaution, the operator takes up his position beside the enclosure not to disturb the air flow. The measurements take place in eight points placed on two horizontal lines, with more than 5 cm from any edge of the sash opening and at least 40 cm from each other. The anemometer calculates and records the mean air velocity measured during 1 minute at each point, with a measurement every 5 seconds.

The sash opening throughout all the tests was 73 cm by 32 cm that is to say a surface S equal to 0.2336 m^2.

Calculation of the mass flow m for the acid test :

- air face velocities measured in two horizontal lines of four points each, gave the following values in m/s : 0.50 ; 0.50 ; 0.52 ; 0.51 ; 0.50 ; 0.50 ; 0.51 ; 0.51. That is to say a mean velocity V equal to 0.50625 m/s.
- extract volume flow rate Q then equal to 425.736 m^3/h.
- desired concentration 50 ppm
- molar weight equal to 36.46 g/mol
- **that is to say a sampling mass flow equal to 1.61 g/min ± 10% (between 1.45 g/min and 1.77 g/min).**

Each test day the ten first minutes were used for the manual setting of the peristaltic pump flow. Without taking into account these first measurements, the minimum and maximum flows measured for each day were :

	Minimum flow (g/min)	Maximum flow (g/min)	Mean flow (g/min)
1st day	0.8	1.9	1.5
2nd day	1.0	2.2	1.4
3rd day	1.9	2.2	2.1
4th day	1.5	1.9	1.7
5th day	1.6	2.0	1.8
6th day	1.5	1.9	1.7
7th day	1.3	1.6	1.4
8th day	1.1	1.8	1.5

It must be noticed that the peristaltic pump had difficulty maintaining a constant flow. The flow was regularly measured under or beyond the acceptance criteria. However these deviations were always quite slight and cannot be considered likely to call advantageously into question the test results.

4. Air sampling

Air samples are taken in three areas :
- « entry » area, upstream from the filtering system (in the enclosure)
- « exit » area, downstream from the filtering system
- « respiratory tracts » area, in front of the enclosure

The air is sampled with a multipoint sampling grid made of Teflon, linked to the analyzer by thin polypropylene and stainless steel tubings, which prevent from any sample contamination.

The « upstream » or « entry » sampling grid is made up of about fifteen equally distributed sampling nozzles, horizontally hanging in the enclosure by four thin stainless steel hooks, 30 cm under the filtering system.

The « downstream » or « exit » sampling grid is made up of about fifteen equally distributed sampling nozzles, horizontally lying on four thin Teflon legs 30 cm upon the filtering system.

The « respiratory tracts » sampling grid is a Teflon rod with five equally distributed sampling nozzles, horizontally hold 52 cm upon the working bench and 5 cm in front of the sash.

Therefore the requirements of the standard about air sampling are fully respected.

5. Analyzer

The air to be sampled is pumped by a Gillian 3500 pump with a flow close to 1 L/min, of which the exact flow is measured each day. A polypropylene cartridge is hermetically set upstream of the pump so that the air goes through the cartridge without loss. A membrane is integrated into the cartridge, this membrane previously being permeated by a $Na_2CO_3/NaHCO_3$ buffer solution. The cartridge is numbered and changed for a new one every 20 minutes.

The permeated cartridges are provided by an independent laboratory, to which each day's used cartridges are sent for determination of chloride anion by Ionic Chromatography. In these conditions the detection limit of the method is said to be 0.05 ppm of hydrochloric acid in the air according to the independent laboratory.

Therefore the requirements of the standard about the analyzer are fully respected.

III. TEST RESULTS

In order to guarantee the test integrity, a dated inviolable seal is put across the test bubble doors, each morning of a test day. After eight hours of evaporation the integrity of the seal is checked before the seal is broken, the evaporation and the filtration are stopped, and a new seal is put during the night. The next morning the night seal is checked, then broken, the filtration is put on and the evaporation is started again, and a new seal is put during the day.

A new hydrochloric acid flask still sealed at its opening is used for the test :
- Fisher Scientific brand
- part no H/1150/21
- serial no 0761569

The acid concentration in the air measured downstream of the filtering system and calculated thanks to the permeated cartridges, and the corresponding evaporated quantity of acid, are set into the following table :

date	time	acid concentration (ppm)	added evaporation (g)
02/10/2008	11:40	0	127,7
02/10/2008	12:00	0	163,0
02/10/2008	12:21	0	200,1
02/10/2008	12:41	0	235,5
02/10/2008	13:02	0	272,7
02/10/2008	13:22	0	308,1
02/10/2008	13:42	0	343,1
02/10/2008	14:03	0	379,4
02/10/2008	14:23	0	413,8
02/10/2008	14:44	0	449,5
02/10/2008	15:04	0	481,9
02/10/2008	15:24	0	512,3
02/10/2008	15:45	0	541,7
02/10/2008	16:05	0	567,5
02/10/2008	16:26	0	592,6
02/10/2008	16:46	0	615,3
02/10/2008	17:06	0	636,9
02/10/2008	17:27	0	658,9
02/10/2008	17:47	0	679,2
02/10/2008	18:08	0	699,4
02/10/2008	18:28	0	717,8
02/10/2008	18:48	0	727,0
09/10/2008	10:30	0	854,3
09/10/2008	10:51	0	886,4
09/10/2008	11:11	0	916,4
09/10/2008	11:32	0	947,6
09/10/2008	11:52	0	976,8
09/10/2008	12:13	0	1005,7
09/10/2008	12:33	0	1033,7
09/10/2008	12:55	0	1063,3
09/10/2008	13:17	0	1092,8
09/10/2008	13:39	0,05	1122,5
09/10/2008	13:59	0	1148,5
09/10/2008	14:20	0	1174,6
09/10/2008	14:40	0	1199,3
09/10/2008	15:01	0	1225,2
09/10/2008	15:21	0	1250,6
09/10/2008	15:42	0	1276,3

09/10/2008	16:02	0	1301,0
09/10/2008	16:22	0	1324,2
09/10/2008	16:43	0	1349,5
09/10/2008	17:03	0	1373,8
09/10/2008	17:24	0	1398,8
13/10/2008	10:21	0	1524,2
13/10/2008	10:41	0	1564,8
13/10/2008	11:02	0,12	1607,5
13/10/2008	11:22	0	1648,1
13/10/2008	11:43	0	1691,0
13/10/2008	12:03	0,12	1731,9
13/10/2008	12:24	0	1774,8
13/10/2008	12:44	0	1816,0
13/10/2008	13:05	0	1859,2
13/10/2008	13:25	0	1900,4
13/10/2008	13:46	0	1943,9
13/10/2008	14:06	0	1985,4
13/10/2008	14:27	0	2029,1
13/10/2008	14:48	0	2072,9
13/10/2008	15:08	0	2114,7
13/10/2008	15:29	0	2158,8
13/10/2008	15:50	0	2203,1
13/10/2008	16:11	0	2247,4
13/10/2008	16:34	0	2296,1
13/10/2008	16:55	0	2340,6
13/10/2008	17:18	0	2389,3
20/10/2008	10:19	0	2518,3
20/10/2008	10:40	0	2553,1
20/10/2008	11:00	0	2586,2
20/10/2008	11:21	0	2621,1
20/10/2008	11:41	0	2654,4
20/10/2008	12:02	0	2689,3
20/10/2008	12:23	0	2724,3
20/10/2008	12:45	0	2761,4
20/10/2008	13:07	0	2798,3
20/10/2008	13:28	0	2833,6
20/10/2008	13:48	0	2867,4
20/10/2008	14:09	0	2903,0
20/10/2008	14:29	0	2936,9
20/10/2008	14:51	0	2974,3
20/10/2008	15:12	0	3010,0
20/10/2008	15:33	0	3045,7
20/10/2008	15:53	0	3079,6
20/10/2008	16:14	0	3114,8
20/10/2008	16:35	0	3150,1
20/10/2008	16:55	0	3184,2
20/10/2008	17:16	0	3220,6
20/10/2008	17:36	0	3255,8
21/10/2008	10:08	0	3361,2
21/10/2008	10:28	0	3395,8
21/10/2008	10:49	0	3432,7
21/10/2008	11:10	0	3469,3
21/10/2008	11:30	0	3504,7
21/10/2008	11:51	0	3542,5

21/10/2008	12:11	0	3578,3
21/10/2008	12:31	0	3614,5
21/10/2008	12:52	0	3652,6
21/10/2008	13:12	0	3688,7
21/10/2008	13:33	0	3726,7
21/10/2008	13:53	0	3762,9
21/10/2008	14:14	0	3801,0
21/10/2008	14:34	0	3837,5
21/10/2008	14:54	0	3873,5
21/10/2008	15:15	0	3911,5
21/10/2008	15:35	0	3947,8
21/10/2008	15:56	0	3985,8
21/10/2008	16:21	0	4031,0
21/10/2008	16:41	0	4067,2
21/10/2008	17:01	0	4103,5
22/10/2008	10:16	0	4216,7
22/10/2008	10:36	0	4249,0
22/10/2008	11:02	0	4291,1
22/10/2008	11:23	0	4326,0
22/10/2008	11:44	0	4361,0
22/10/2008	12:04	0	4394,5
22/10/2008	12:24	0	4428,3
22/10/2008	12:45	0	4464,0
22/10/2008	13:05	0	4498,4
22/10/2008	13:26	0	4535,0
22/10/2008	13:46	0	4569,6
22/10/2008	14:06	0	4604,0
22/10/2008	14:28	0	4641,8
22/10/2008	14:50	0	4679,2
22/10/2008	15:11	0	4715,7
22/10/2008	15:31	0	4750,5
22/10/2008	15:52	0	4787,3
22/10/2008	16:12	0	4822,3
22/10/2008	16:33	0	4859,3
22/10/2008	16:59	0	4905,6
22/10/2008	17:20	0	4943,2
22/10/2008	17:40	0	4970,1
23/10/2008	14:03	0	5367,9
23/10/2008	14:26	0	5400,6
23/10/2008	14:47	0	5430,4
23/10/2008	15:07	0,109	5458,8
23/10/2008	15:28	0	5488,5
23/10/2008	15:50	0,057	5519,6
23/10/2008	16:14	0,088	5553,5
23/10/2008	16:34	0	5581,6
23/10/2008	16:55	0,078	5610,9
23/10/2008	17:16	0,116	5639,7
04/11/2008	10:07	0,091	5753,9
04/11/2008	10:27	0	5787,4
04/11/2008	10:47	0	5820,8
04/11/2008	11:08	0,081	5855,9
04/11/2008	11:29	0	5890,5
04/11/2008	11:49	0	5923,3
04/11/2008	12:10	0	5958,2

04/11/2008	12:30	0,621	5991,7
04/11/2008	12:50	0,115	6025,2
04/11/2008	13:11	0	6060,2
04/11/2008	13:32	0	6094,5
04/11/2008	13:52	0	6125,6
04/11/2008	14:13	0	6157,3
04/11/2008	14:33	0	6186,5
04/11/2008	14:54	0	6215,4
04/11/2008	15:14	0	6242,8
04/11/2008	15:34	0	6269,8
04/11/2008	15:55	0	6297,7
04/11/2008	16:16	0	6325,2
04/11/2008	16:36	0	6350,7
04/11/2008	16:58	0	6377,9

It is noticed that the concentration of 1% of the OEL of hydrochloric acid (0.05 ppm) is reached downstream of the filtering system after filtering 5459 grammes of commercial solution of hydrochloric acid (35.88% w/w), that is to say **2729 grammes for each filtration module**, after **63 hours and 33 minutes** of evaporation. This duration is then the normal operating time.

$1/12^{th}$ of the normal operating time is equal to 5 hours and 18 minutes. The test was conducted for only an additional time of about 2 hours after the normal operating time, so that it cannot be fully maintained that the concentration corresponding to 50% of the OEL (2.5 ppm) was not reached at the end of the safety operating time. However the concentrations measured during these 2 hours are so low that it looks very reasonable to affirm that 50% of the OEL would not have been reached if the test had been conducted for a sufficient time.

ANNEXES

- TEST PROCEDURE
- MEASUREMENT EQUIPMENTS
- CALIBRATION CERTIFICATES
- WEIGHT DATA TABLE
- RELATIVE HUMIDITY AND TEMPERATURE DATA TABLE
- MISCELLANEOUS