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# TEST REPORT

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REPORT no  
Clyo8R0366 PMa/PMa

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



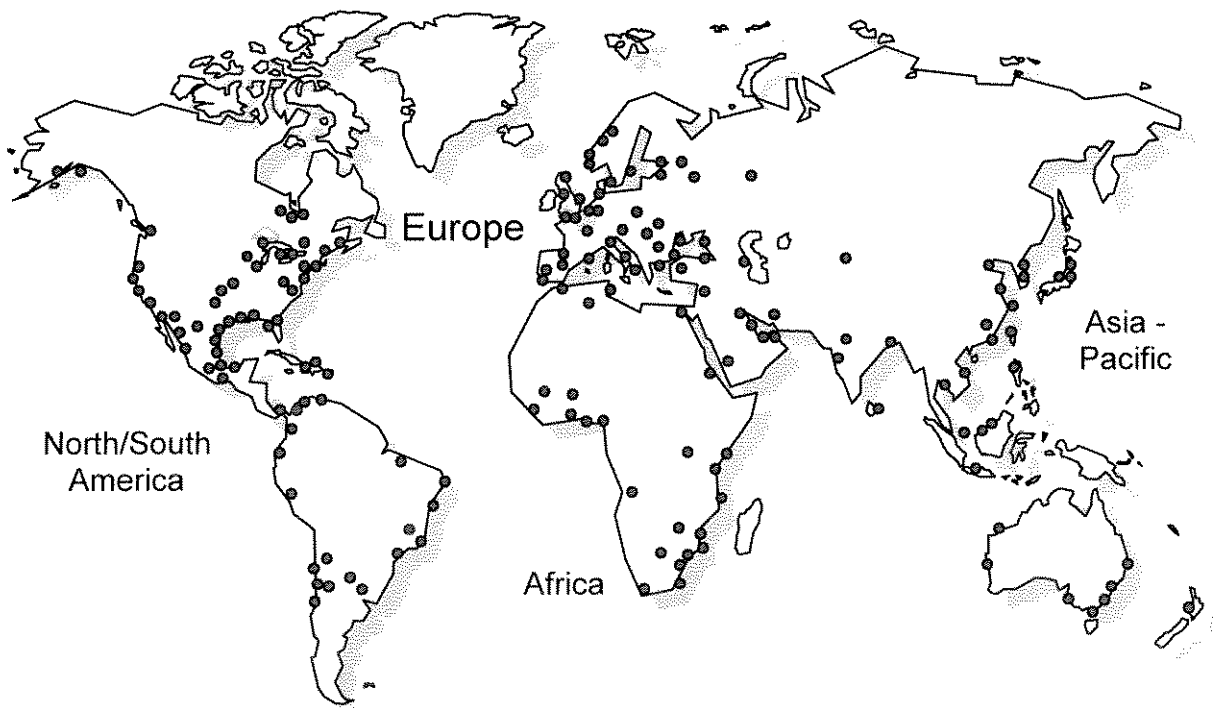
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At the request of : **ERLAB S.A.S.**

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## **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  
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27104 VAL DE REUIL cedex - France**

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

The intervention was performed on June 30<sup>th</sup> and July 4<sup>th</sup>, 2008 by :

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**The results described in the present report concern only the equipments subjected to tests.**

**Forbidden reproduction of the present test report without the authorization of INTERTEK TESTING SERVICES.**

**This report comprises 219 pages (with annexes).**

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## 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 each independent filtering module subjected to tests was able to filter 673 grammes of isopropanol or 914 grammes of cyclohexane before reaching a reject concentration, downstream from the filtering system, of 1% of the retained Occupational Exposure Limit for each chemical agent (highest concentration imposed by the standard).**

**If several modules are parallel installed on an enclosure, these filtration values are of course to be multiplied by the number of modules.**

**Moreover it was noticed that the safety operating time greatly exceeds 1/12<sup>th</sup> of the normal operating time, as asked by the standard, for both isopropanol and cyclohexane tests.**

**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 volatile organic compounds.**

However these conclusions must not prejudice the soon-coming test results that the prototype may obtain in accordance with other requirements of NF X 15-211, particularly the filtration test for acid vapors 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 from 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<sup>th</sup> 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 from 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 « isopropanol » and « cyclohexane » tests. The « hydrochloric acid » test has not been performed yet at the day of the writing of the present report.

## **A. NORMATIVE OPERATING CONDITIONS**

### **1. Temperature and relative humidity**

The tests shall be performed at  $20\pm 2^{\circ}\text{C}$  and with a relative humidity between 40% and 70%. The heating unit shall not increase the internal temperature of the enclosure by more than  $5^{\circ}\text{C}$  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  $\pm 10\%$  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 organic vapors the trapping of a known volume of the air to be sampled through an adsorbing cartridge. This sample shall then be desorbed with a carbon disulfide solution ( $\text{CS}_2$ ) before being analyzed with Gas Chromatography with a FID detector.

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 wire-free connection to an acquisition software.

Temperature and relative humidity raw data are attached to the present report, with corresponding graphics.

Isopropanol test :

- relative humidity between 41% and 47,8%
- temperature inside the enclosure between 24,1°C and 33,1°C
- temperature outside the enclosure between 24,1°C and 30,7°C
- temperature difference between inside and outside the enclosure never more than 2,5°C

Cyclohexane test :

- relative humidity between 46,3% and 54%
- temperature inside the enclosure between 25,2°C and 31,2°C
- temperature outside the enclosure between 24,7°C and 29,1°C
- temperature difference between inside and outside the enclosure never more than 2,2°C

**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 exceed the acceptance criteria of the standard ( $20^{\circ}\text{C} \pm 2^{\circ}\text{C}$ ). However numerous references<sup>1</sup> 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<sup>3</sup>.

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<sup>3</sup>.

**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 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.**

<sup>1</sup> LE CLOIREL, Les composés organiques volatils (COV) dans l'environnement, Tec&Doc Ed., 1998, 454455

### 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 150°C).

A flask containing the chemical agent lies on the plate of a laboratory balance (0,1 g precision). The flask is hermetically closed. The cap is pierced by a glass pipette linked to a Viton tube 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<sup>3</sup>/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 :

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

The extract volume flow rate  $Q$  is first calculated as a function of the surface of the sash opening  $S$  (in m<sup>2</sup>) 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 :

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

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 35 cm that is to say a surface  $S$  equal to 0,2555 m<sup>2</sup>.

Calculations of the mass flows  $m$  for the isopropanol and the cyclohexane tests :

- **Isopropanol test**
  - air face velocities measured in two horizontal lines of four points each, gave the following values in m/s : 0,57 ; 0,52 ; 0,48 ; 0,45 ; 0,54 ; 0,49 ; 0,43 ; 0,44. That is to say a mean velocity  $V$  equal to 0,49 m/s.
  - extract volume flow rate  $Q$  then equal to 450,7 m<sup>3</sup>/h.
  - desired concentration 200 ppm
  - molar weight equal to 60,10 g/mol

- that is to say a sampling mass flow equal to 4,03 g/min  $\pm$  10% (between 3,63 g/min and 4,43 g/min).
- **Cyclohexane test**
  - air face velocities measured in two horizontal lines of four points each, gave the following values in m/s : 0,51 ; 0,48 ; 0,49 ; 0,42 ; 0,53 ; 0,47 ; 0,45 ; 0,45. That is to say a mean velocity V equal to 0,475 m/s.
  - extract volume flow rate Q then equal to 436,9 m<sup>3</sup>/h.
  - desired concentration 200 ppm
  - molar weight equal to 84,16 g/mol
  - that is to say a sampling mass flow equal to 5,47 g/min  $\pm$  10% (between 4,92 g/min and 6,02 g/min).

The weight recording during the isopropanol test shows that after the ten first minutes used for the manual setting of the peristaltic pump flow, the mass flow always remained between 3,9 g/min and 4,3 g/min, which remains inside the acceptance criteria.

The weight recording during the cyclohexane test shows that after the five first minutes used for the manual setting of the peristaltic pump flow, the mass flow always remained between 5,0 g/min and 5,5 g/min, which remains inside the acceptance criteria.

#### 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 analyzer is a Gas Chromatograph Varian CP-3800 equipped with a capillary column CP-Sil 8 CB Low Bleed/MS and a FID detector. Continuous air sampling from one of the three sampling ways (« entry », « exit » or « respiratory tracts ») is allowed thanks to a specific system using several valves, driven by the software driving the chromatograph itself. The air sample is then directed to a cryogenic trap cooled with CO<sub>2</sub>, which concentrates the possibly present chemical agents in the air during a given time. The trap is finally quickly heated which desorbs the possibly present chemical agents towards the chromatograph injector. Separation, identification and quantification of the chemical agents are then classically performed by external calibration. All operations are stand-alone once the sample list is set up specifying the desired order for samplings.

**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 time a test begins. Once the end of the test is reached, the integrity of the seal is checked before the seal is broken and the test is stopped.**

## A. « ISOPROPANOL » TEST

### 1. Calibration

Increasing concentrations of isopropanol are evaporated in the fume hood functioning its normal way, and the air in the enclosure is analyzed (« entry »). The operator manually sets up the peristaltic pump flow, then allows the evaporation to stabilize a few minutes before analyzing by chromatography. The sampling mass flow is calculated by weight difference during several minutes. The following table is obtained :

sampling time	chromatographic peak area (mV/s)	mean evaporation per minute during the 5 minutes before sampling (g)
12:04	56458	0,7
12:29	68420	0,7
12:53	75471	0,7
13:18	77156	0,7
13:43	164437	2,2
14:08	201083	2,2
14:31	273326	3,1
14:56	275235	3,2
15:22	406537	5,1

A curve (found in annex) linking the surface of the chromatographic peak of isopropanol to the evaporation mass flow is drawn. A linear trend curve is drawn, giving a  $R^2$  factor equal to 0,9885 which is very reasonable considering the general working difficulty in the field of gas analysis.

Therefore the calibration shows a linear response of the analyzer for isopropanol peak areas lower or equal to about 400000 mV/s.

### 2. Test

A new isopropanol flask still sealed at its opening is used for the test :

- Fisher Scientific brand
- part no P/7490/21
- serial no 0879418

The evaporation begins at 9:02 am. Once the peristaltic pump mass flow is stabilized, two « entry » samples are first analyzed, a third « entry » sample being analyzed at mid-day. These three samples give a mean chromatographic peak area of 418130 mV/s for the evaporated concentration of 200 ppm in the « entry » area. This value will then be the

calibration point for the following concentration measurements in the « exit » and « respiratory tracts » areas.

After reprocessing the chromatograms and compiling the weight data, the following table is obtained :

sampling time	sampling area	chromatographic peak area (mV/s)	concentration (ppm)	evaporated mass (g)
9:54	entry	400849	200	195,1
10:19	respiratory tracts	29136	13,9	297,5
10:44	entry	403949	200	400,0
11:09	exit	23649	11,3	502,5
11:34	respiratory tracts	4360	2,1	605,1
12:00	exit	2207	1,1	711,9
12:25	exit	959	0,5	814,7
12:51	exit	0	0,0	921,8
13:16	exit	0	0,0	1024,9
13:42	entry	449594	200	1132,3
14:08	exit	22319	10,7	1239,9
14:34	exit	9987	4,8	1347,6
15:01	exit	22254	10,6	1459,5
15:27	exit	40638	19,4	1567,3
15:54	exit	76452	36,6	1679,3
16:21	exit	154112	73,7	1791,4
16:48	exit	251746	120,4	1903,4
17:15	exit	357586	171,0	2014,9

At first, a certain « memory » effect of the system must be noticed : a concentrated sample (« entry ») visibly makes the following samples more concentrated than they should. This effect disappears after the fourth injection following the « entry » injection.

It is noticed that the concentration of 1% of the OEL of the isopropanol (4 ppm) is reached downstream from the filtering system after filtering 1347 grammes, that is to say **673 grammes for each filtration module, after 5 hours and 32 minutes** of evaporation. This duration is then the normal operating time. It has to be noted that this duration may have been a little longer if an « entry » sample had not been analyzed about one hour before, which obviously had a harmful influence on the measured concentration. However the objective test results make us take into account the actually measured concentrations, not what the concentrations could have been if the test had unfolded another way.

$1/12^{\text{th}}$  of the normal operating time is equal to 28 minutes. The downstream concentration reached at the end of the normal operating time extended by  $1/12^{\text{th}}$ , that is to say after 6 hours and 00 minute (15:02) is about 11 ppm which is greatly lower than 50% of the OEL (200 ppm).

## B. « CYCLOHEXANE » TEST

### 1. Calibration

Increasing concentrations of cyclohexane are evaporated in the fume hood functioning its normal way, and the air in the enclosure is analyzed (« entry »). The operator manually sets up the peristaltic pump flow then allows the evaporation to stabilize a few minutes before analyzing by chromatography. The sampling mass flow is calculated by weight difference during several minutes. The following table is obtained :

sampling time	chromatographic peak area (mV/s)	mean evaporation per minute during the 5 minutes before sampling (g)
14:02	136027	0,3
14:26	176312	0,3
14:51	378457	0,6
15:15	454679	0,6
15:39	992371	1,9
16:04	1208209	1,9
16:28	1618519	2,7
16:52	1831112	2,7

A curve (found in annex) linking the surface of the chromatographic peak of cyclohexane to the evaporation mass flow is drawn. A linear trend curve is drawn, giving a  $R^2$  factor equal to 0,9763 which is very reasonable considering the general working difficulty in the field of gas analysis.

Therefore the calibration shows a linear response of the analyzer for cyclohexane peak areas lower or equal to about 1800000 mV/s.

### 2. Test

A new isopropanol flask still sealed at its opening is used for the test :

- Fisher Scientific brand
- part no C/8920/21
- serial no 0569396

The evaporation begins at 8:57 am. Once the peristaltic pump mass flow is stabilized, three « entry » samples are first analyzed, giving a mean chromatographic peak area of 1910750 mV/s for the evaporated concentration of 200 ppm in the « entry » area. This value will then be the calibration point for the following concentration measurements in the « exit » and « respiratory tracts » areas.

After reprocessing the chromatograms and compiling the weight data, the following table is obtained :



sampling time	sampling area	chromatographic peak area (mV/s)	concentration (ppm)	evaporated mass (g)
9:42	entry	1628357	200	231,6
10:07	entry	2218408		365,8
10:32	entry	1885486		500,0
10:56	exit	34973	3,7	628,9
11:21	respiratory tracts	23430	2,5	763,2
11:46	exit	19056	2,0	897,5
12:10	exit	15303	1,6	1026,6
12:35	exit	12846	1,3	1161,0
12:59	exit	11296	1,2	1290,1
13:24	exit	10752	1,1	1424,6
13:49	exit	12566	1,3	1558,9
14:14	exit	17389	1,8	1693,4
14:39	exit	28327	3,0	1827,6
15:04	exit	51445	5,4	1961,7
15:29	exit	97100	10,2	2095,7
15:54	exit	162429	17,0	2229,6
16:19	exit	248626	26,0	2363,2
16:44	exit	351022	36,7	2496,9

It is noticed that the concentration of 1% of the OEL of the cyclohexane (3 ppm) is reached downstream from the filtering system after filtering 1828 grammes, that is to say **914 grammes for each filtration module**, after **5 hours and 42 minutes** of evaporation. This duration is then the normal operating time.

$1/12^{\text{th}}$  of the normal operating time is equal to 28 minutes. The downstream concentration reached at the end of the normal operating time extended by  $1/12^{\text{th}}$ , that is to say after 6 hours and 10 minute (15:07) is about 6 ppm which is greatly lower than 50% of the OEL (150 ppm).

# ANNEXES

- **TEST PROCEDURE**
  
- **MEASUREMENT EQUIPMENTS**
  
- **CALIBRATION CERTIFICATES**
  
- **WEIGHT DATA TABLES AND CHROMATOGRAMS**
  
- **MISCELLANEOUS**