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A New State of the Art Stationary Dynamic Dilution Olfactometer

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Public awareness towards environmental odours has increased with higher living standards. Still, nowadays, no instrument can yet replace the human's specific perception of odours because of the complexity of the relationship and interaction between the odour constituting gases. Olfactometry, which is the science of measuring odours, remains the only statistical method to characterize odours and their effects on human perception. This relatively recent science has evolved since the early 1970's and is now regulated by international guidelines available in Europe (CEN 13725, 2003; VDI 3882, 2003) and North America (ASTM 679, 2011). These guidelines recommend the use of a specific instrument to characterise odours using a jury of "noses". This instrument is called an olfactometer. This paper will present a state-of-the-art stationary dynamic dilution olfactometer designed by Consumaj. This dynamic olfactometer meets the European and North American standards in olfactometry analysis. This paper will emphasize the process of design and development involved in the concept of this dynamic olfactometer in order to meet the different international standards and to provide accurate and precise odour measurements.
This stationary olfactometer, named Onose-8®, is presently in operation at Consumaj laboratories, in St Hyacinthe, Canada. This olfactometer is designed to accommodate up to 16 assessors simultaneously, which meets the VDI 3882 (2003) standards. This particularity is made possible because of its nonagon (9-sided) shape providing ergonomic features for more comfort, space and ease of work to the assessors. The dilution of odorant samples with fresh air is performed using mass flow controllers that can also be automatically verified and calibrated using a protocol provided with the interface software that controls the olfactometer.

1. Presentation of the olfactometer

The Onose-8® olfactometer is a stationary dynamic dilution olfactometer allowing 8 panel members to simultaneously perform olfactometric analyses. This number can be increased to 16 assessors (2 assessors per sniffing station). This feature meets the VDI standards while significantly reducing duration of the analysis. 3 sniffing tubes are available per sniffing station for triangular forced choice odour analysis. Another sniffing tube, for a total of 4 per sniffing station, can be added to proceed with n-butanol reference intensity scale analysis. Other analysis techniques that can be performed with the Onose-8® olfactometer are: yes/no detection method, validation of assessor's individual threshold using n-butanol, hedonic scale analysis, subjective methods, etc. Since the olfactometer can be customised, other types of analysis techniques can be performed by the olfactometer in accordance with the user's needs.

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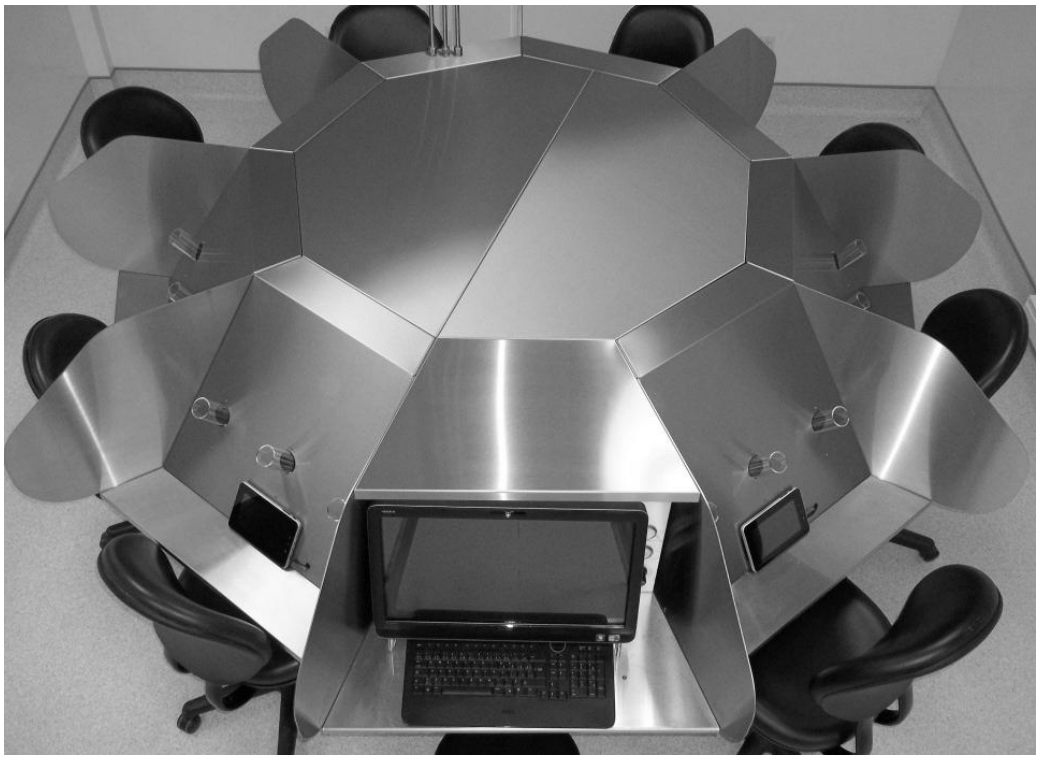

Figure 1: General design and structure of the 9-sided (nonagon) Onose-8® stationary dynamic dilution olfactometer operated at Consumaj laboratories in Canada.

The Onose-8® olfactometer also comes with a powerful operating system interface allowing an all-around control of the many features of the olfactometer. This software is intuitive and can also be adapted to the client's specific needs. Real-time presentation of the assessors' voting results and automatic production of analysis certificate are some of the many particularities provided by the interface software of the olfactometer.

2. Conformity to international guidelines

The main purpose of an olfactometer is to assess air samples that have an odour concentration above the detection threshold of the human nose. The main design criteria in the process of producing a new generation of dynamic olfactometer is the need of meeting international standards in olfactometry. The main standards that describe the general design requirements for an olfactometer are the European standards En 13725 (2003) and VDI 3882 (2003) and the North American standard ASTM 679 (2011).
The Onose-8® olfactometer has been designed and developed in agreement with these international standards. This olfactometer can thus be used to perform olfactory analyses and to present results in accordance to the European and North American standards.

3. Ergonomic and comfort

3.1 Comfort during odour analyses

The duration of odour analyses may vary from one project to another. Some of them may last over a relatively long period of time. Therefore, no matter how long an analysis session lasts, the panel members must always remain motivated and alert at providing rigorous and repeatable results among the presentations. Some of the aspects giving a good working environment to assessors, and to the

operator as well, are directly related to the olfactometer. Such characteristics are its ergonomic features and comfort.

The Onose-8® dynamic olfactometer is presented as a 9-sided (nonagon) desk composed of 8 individual sniffing stations and 1 operational station. The seat height and the desk size allow assessors to rest their arms and inhale through the sniffing tubes without adopting a bend-over position. With their angle position, the sniffing tubes are easy to reach and minimum movements from assessors are necessary during the sniffing and voting process. Furthermore, the olfactometer is large enough for the assessors to stretch their legs. The 7" wide touch screen electronic tablets used by the assessors to record their voting results after sniffing the odours is large enough to easily enter required data and to see clearly the indications presented to them on these electronic tablets.

The Onose-8® olfactometer is also very handy for the operator in charge of this instrument. In fact, the operating station is composed of a 24" wide touch screen all-in-1 computer. The operator's seat and screen are at the appropriate heights for the operator to run the olfactometer while having at the same time a good view of all assessors before their respective sniffing stations around the olfactometer.

3.2 Ergonomic and maintenance operations

The olfactometer's design quality does not limit itself to the comfort of the personnel during odour analyses. The ergonomics of the olfactometer is also reflected during maintenance procedures. In fact, all important, vital, components of the olfactometer are located behind the operational station on a stretchable drawer. This drawer supports all components of the fluidic circuit that requires specific attention during maintenance operations. This drawer can be pulled out beneath the olfactometer's main structure in order to bring the components easily at reach to work with. This unique feature renders the maintenance easy to carry on.

Figure 2: Presentation of the drawer supporting the main components of the fluidic circuit of the olfactometer. This drawer is located behind the operating station and can be pulled out from under the olfactometer's main structure.

4. Presentation of the fluidic circuit

The fluidic circuit of the Onose-8® olfactometer is made entirely of FEP, stainless steel and glass. The flow rates of the odorous samples or of the fresh air for dilution purposes are determined by precise mass flow controllers having a variability of the repeatability of their flow rate readings below 0.2 %. These mass flow controllers also provide a dilution range from 2^4 to 2^{21} (16 to 2,097,152). The stabilisation time required by the mass flow controllers to reach the proper flow rate is below 5 s in average. The flow rate and velocity of the odorant air reaching the assessors at the outlet of the sniffing tubes can also be modified to fit a specific international standard required for the analysis.

4.1 Sample vacuum input method

Most of the olfactometers use a pressurized cylindrical container to expulse the odorant air samples out of the bags directly to the olfactometer fluidic circuit. The Onose-8® olfactometer, however, uses vacuum to introduce the odorant air sample into the olfactometer. Since there is no need for a container holding samples and no need to wait until the cylinder has reached the proper pressure, this feature saves room and time. Furthermore, this vacuum based sample input method allows to perform direct or on-line olfactometry analysis (without any delay between the odour sampling procedure and the measurements). This characteristic is also useful to analyse air in the head column of a closed environment.

4.2 Carrying gas and dead space

Once the mass flow controllers have reached their stability, the odorant sample automatically reaches the sniffing tubes with no delay, even with a very low odour flow rate. This particularity is due to the use of a carrying gas system that brings the odorant sample quickly to the sniffing tubes. This allows the panel members to immediately assess the presented odorant samples as soon as the mass flow controllers have reached their stability. Furthermore, the latent odour that may be left into the fluidic circuit between two presentations, also called the fluidic circuit dead space, is very limited. In fact, the volume of dead space in the circuit is below 2.1×10^{-4} m^3 (representing the volume of a 4 mm inside diameter and 0.41 m long FEP tubing). The odour present in this dead space is flushed through the carrying gas to the sniffing tubes before the mass flow controllers are stabilised. The assessors are thus not in contact with the leftover odours from a previous presentation.

5. Operating interface software

An interface software is used by the person in charge of the analysis to operate the olfactometer. This software gives the choice of an automatic or manual operating mode. The manual operating mode allows the operator to completely control every aspect of the olfactometric analysis while the automatic operating mode requires only minimum operator's intervention to accomplish complete and accurate odour analysis. This software is easy to use and intuitive. This software also shows the assessors' real time voting results. Furthermore, the software offers a follow up of the mass flow controllers' readings. A powerful calibration protocol is also included in the software. In addition to the automatic production of a certificate of analysis presenting the analysis results, the operating software allows the input of key information regarding the odour samples, panel members and clients' information. These information are used to produce a complete follow up of the samples and their results.

5.1 Automatic vs. manual operating mode

Within the interface software, an automatic and manual operating modes are presented to the operator. The automatic operating mode featured with the software provides the operator the opportunity to only apply minimal intervention over the analysis. The operator only decides of the dilution factor required for the analysis undergone, while the software automatically executes all other operations. Furthermore, the automatic operating mode proposes a series of the most frequently used operations when operating an olfactometer. For instance, a system purging protocol or a blank sample preparation are only a few of the many automatic operating protocols that can be automatically operated by the olfactometer.

On the opposite, the operator can choose to completely control every components of the fluidic circuit and regulate the mass flow controllers and valves . This mode is useful for advanced operators willing to execute their own olfactometry analysis with minimum assistance from the interface software. The manual operating mode can be useful to retry a presentation having exactly the same characteristics than one previously executed or to choose the sniffing tube that will receive the odorant sample.
In any cases, the interface software functionalities can be modified and customized to fit the client's own requirements for specific olfactometric analyses.

5.2 Real time results presentation

The main page of the operating interface software presents a scheme of the olfactometer and information about assessors' real time voting results. This window is refreshed each time a new result is submitted by a panel member and this results is presented on the interface software. This feature helps the operator to interpret the results and decide how the analysis should be performed according to the assessors' results.

5.3 Automatic calibration protocol

The interface software of the Onose-8® olfactometer comes with a protocol to verify and calibrate, if needed, the mass flow controllers. The calibration decreases the reading errors of these components. This protocol offers a step-by-step procedure guiding the operator through all the steps required to perform a validation and/or calibration of the mass flow controller readings.

5.4 Feedback on mass flow controller readings

The olfactometer interface shows in real time the flow rate received and the flow rate reading of the different mass flow controllers. This allows the operator to see directly if the mass flow controllers provide the proper flow rate. This feature is an advantage over set venturi openings. With mass flow controllers, the flow rates of odours and fresh air over the entire fluidic circuit are known at all times, which is necessarily the case with set venturi openings.

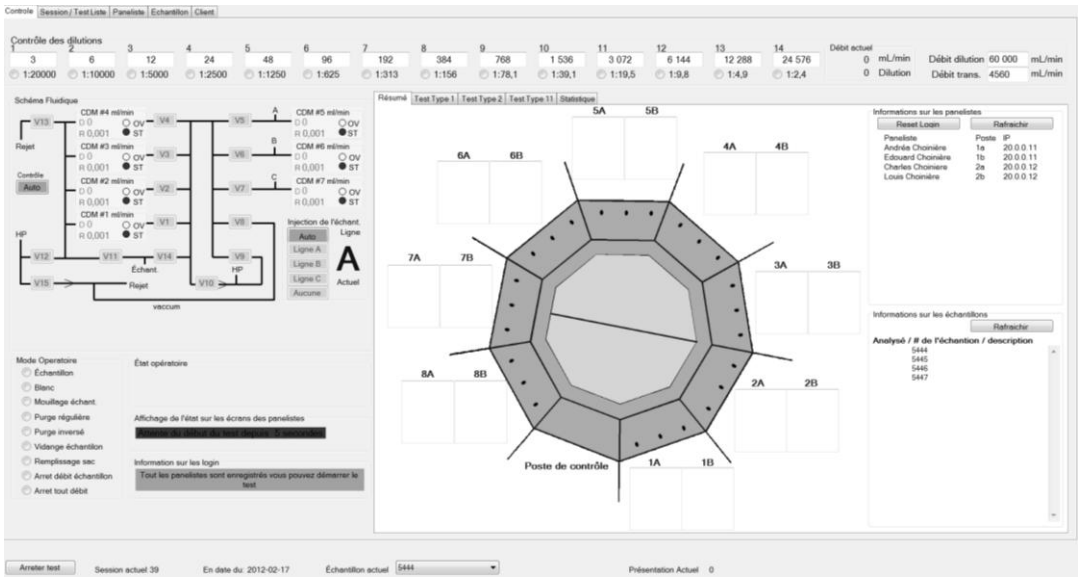

Figure 3: The user friendly interface of the operating software helps the operator to run the Onose-8® olfactometer. This interface features a real-time presentation of the assessors' results and gives vital information about the state of the olfactometer. This interface also offers two operating modes: automatic and manual.

Table 1: Onose-8® olfactometer technical information

Manufacturer	Consumaj Inc.	
Model	Onose-8®	
Operation interface software	Olfaware®	
Types of analysis	• Triangular Forced Choice	• Yes/No Method
	• Assessors validation	• Hedonic Tone
	• Others (according to client's requirements)	
Standards	• EN13725	• VDI 3882
	• ASTM 679	
Number of sniffing stations	8	
Number of sniffing tubes per station	Up to 4	
Number of assessors	Up to 16	
Dilution factor	• 2^4 to 2^{17} (standard)	• 2^4 to 2^{21} (optional)
Dilution step factor	Variable	
Average time of analysis (EN 13725)	• 6 minutes (8 assessors)	• 10 minutes (16 assessors)
Time required for flow rate stabilisation	< 5 seconds	
Presentation flow rate	20 L/min to 35 L/min	
Air speed at exit of sniffing tubes	0.21 m/s to 0.37 m/s	
Accuracy of mass flow controllers	Error < 0.2 % (0 % to 20 % full scale)	
	Error < 1 % (20 % to 100 % full scale)	
Repeatability of flow rates	±0.2% of flow rate	
Fluidic circuit material	• FEP	• Stainless steel
	• Glass	
Power requirements	110-230 VAC 50/60 Hz, 10 Amp	
Dimensions	Width: 2.5 m; Length: 2.5 m (drawer closed)	
	Width: 2.5 m; Length: 3.5 m (drawer opened)	

6. Conclusion

The Onose-8® stationary dynamic dilution olfactometer is a state-of-the-art olfactometer built and designed under international guidelines; it is a very powerful tool which uses different methods for odour analysis. This olfactometer has ergonomic features favouring comfort to the assessors and the operator. It is built to facilitate the maintenance of its components. Furthermore, its operating interface is intuitive and offers a variety of configurations according to the operator's needs.

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