PMI SCIENCE
PHILIP MORRIS INTERNATIONAL

PROCEDURE FOR ACCURATELY QUANTIFY WATER IN MAINSTREAM AEROSOL OF THE TOBACCO HEATING SYSTEM (THS or IQOS) USING THE *IN SITU* EXTRACTION METHOD

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1 Introduction

Because the Tobacco Heating System (THS or IQOS, its commercial name) heats tobacco without burning it (combusting) to generate a nicotine-containing aerosol, the composition of the aerosol is significantly different form the smoke generated by combustible product. Indeed, IQOS aerosol contains about 80% of water. Due to this high content of water, the accurate determination of water in IQOS aerosol is addressed by using a modified (compared to the procedure described in ISO 4387 method) extraction methodology which is based on an *in situ* extraction. Accurate determination of water is of importance as this parameter is used to calculate the ISO NFDPM (Nicotine Free Dry Particulate Matter). Even though NFDPM can be calculated according to ISO in IQOS aerosol by subtracting the water and nicotine from the total particulate matter, this parameter is not relevant to be reported for this product. Indeed, the NFDPM, also called "Tar" in combustible products, contains mainly glycerol and other tobacco constituents that are transferred by heating the tobacco. In addition as opposed to combustible product we have demonstrated that IQOS aerosol does not contain any solid particles[1]. It is therefore incorrect to express it as "Tar" for IQOS. However, if for any reason (e.g. regulation) NFDPM must be reported or printed for IQOS, the measurement of water must be done accurately as it has a significant impact on NFDPM.

This document provides a detailed description of these modifications and step by step instructions for collecting the aerosol of IQOS using an *in situ* extraction method for the quantification of water, nicotine and glycerol.

1 Scope

This document describes the accessories and the procedures for collecting the IQOS aerosol for the purposes of accurately determining the level of water in the aerosol using an *in situ* extraction method. 2.2 describes the methodology for trapping total particulate matter and extracting the total mass of water in the IQOS aerosol, in order to subsequently dosing it analytically (e.g. chromatography).

The following ISO norm is directly applicable:

- ISO 10362: Determination of water in smoke condensates – Part 1: Gas Chromatographic method

Other ISO norms, however, such as "ISO 4387: Cigarettes – Determination of total nicotine-free dry particulate matter using a routine analytical smoking machine" result in erroneous results if applied without adaptation specifically for the IQOS aerosol. In particular, the ISO 4387 methodology fails to properly recover the total amount of water and must be modified as described in chapter 2.2.

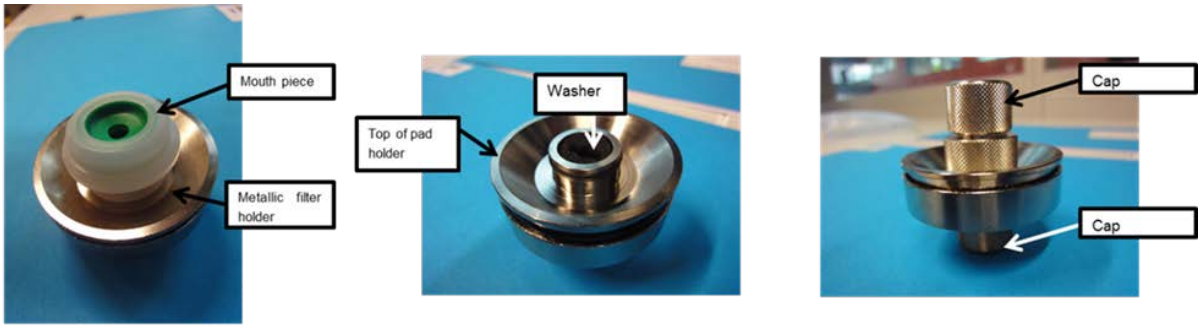
[1] Investigation of solid particles in the mainstream aerosol of the Tobacco Heating System THS2.2 and mainstream smoke of a 3R4F reference cigarette; P Pratte and al., Human and Experimental Toxicology (HET) 1-6, 2016 (http://journals.sagepub.com/action/doSearch?AllField=Cosandey+AND+pratte&SeriesKey=hetb)

For the aerosol generation and collection please refer to the document [Procedure for generation and testing of mainstream IQOS aerosol using linear smoking machine] also available on PMIscience.com

2 Description of the Method

2.1 Principle

The principle of the *in situ* extraction is based on solvent extraction of the Cambridge pad filter by flushing the solvent through the Cambridge pad holder without opening it at the end of the aerosol collection. By doing so, the water cannot be lost by evaporation or any leaking while opening the Cambridge pad holder. In order to make it possible special metallic Cambridge pad holders have been designed for 44-mm diameter Cambridge pad filter. The holder contains the neoprene washer (as seen in the picture below). This enable to apply the ISO method for the proper determination of the TPM which is done by weighing the holder before after the aerosol collection without the mouth piece. So as to avoid any loss of water the holder is equipped with connector sealed with o-ring on which metallic caps can be placed. The metallic caps contain holes hermetically closed with a septum that will be pierce by the syringe needle during the *in situ* extraction.



2.2 Sample preparation prior to the analyses of water

ISO standards prescribe methods for the quantification of certain analytes and constituents in cigarette smoke, such as nicotine (ISO 10315, 2013), water (ISO 10362-1, 1999; ISO 10362-2, 2013), CO (ISO 8454, 2007), benzo[a]pyrene (ISO 22634, 2008), TPM and NFDPM (ISO 4387, 2000), and menthol (ISO 13110, 2012). However, these methods were developed specifically for cigarette smoke, which is fundamentally distinct from heated tobacco product aerosol. A critical distinction is the fact that IQOS aerosol is approximately 80% water, while cigarette smoke contains only about 10% water. Standardized testing and quantification methods such as the ISO and Health Canada methods were not developed to measure aerosols containing principally water, which evaporates rapidly or is absorbed

during the measurement process.[2] High levels of evaporation and absorption result in substantially understated measurements of the total levels of water in the aerosol.[3] In turn, the calculations of other analytes that are based on the amount of water in the aerosol are inaccurate. In particular, values for nicotine free dry particulate matter (NFDPM)[4] can be overstated by as much as 100%[2].

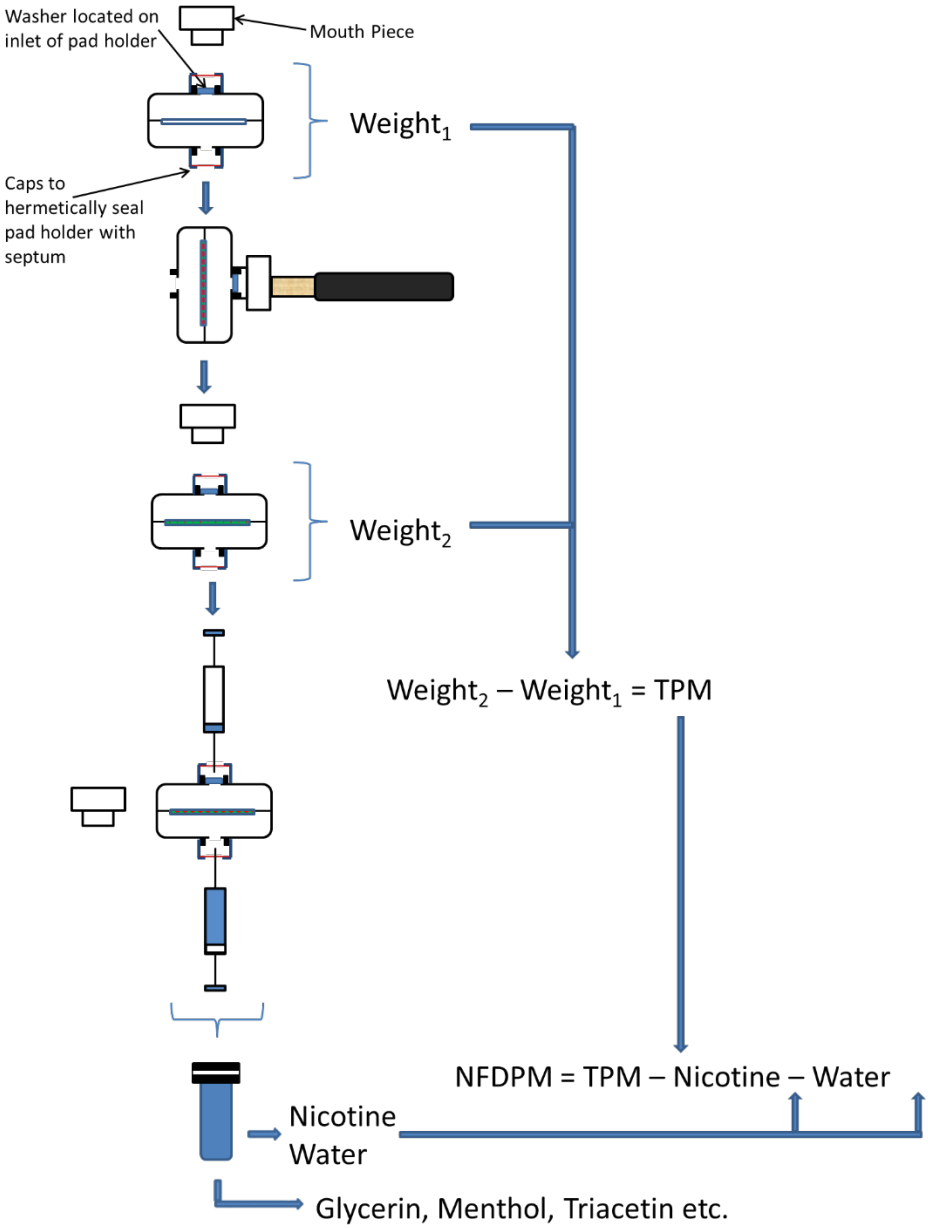
To address this issue, PMI has developed and validated a modified methodology that traps the aerosol particulate matter in the same way as the standard method but where the filter pad can be extracted *in situ* without opening the filter pad holder, thus avoiding water losses.

[2] D. Ghosh / Jeannet, Beiträge zur Tabakforschung International, Volume 26, Issue 2 (Jul 2014), (www.degruyter.com/view/j/cttr.2014.26.issue-2/cttr-2014-0008/cttr-2014-0008.xml)

[3] Using these methods, between 19% and 24% of water in the aerosol is lost to evaporation when the filter housing is opened to remove the filter pad (on which TPM, including water, is trapped) or when the filter is handled manually, and even to absorption by the plastic filter housing material itself.

[4] NFDPM in the IQOS aerosol is distinctly different from NFDPM in cigarette smoke. IQOS aerosol NFDPM is made up of between 30% and 45% glycerol, contains lower levels HPHCs than cigarette NFDPM (by about 90% on average), and does not contain solid particles like cigarette smoke NFDPM.

The process for calculating NFDPM using *in situ* extraction is represented in the scheme below:



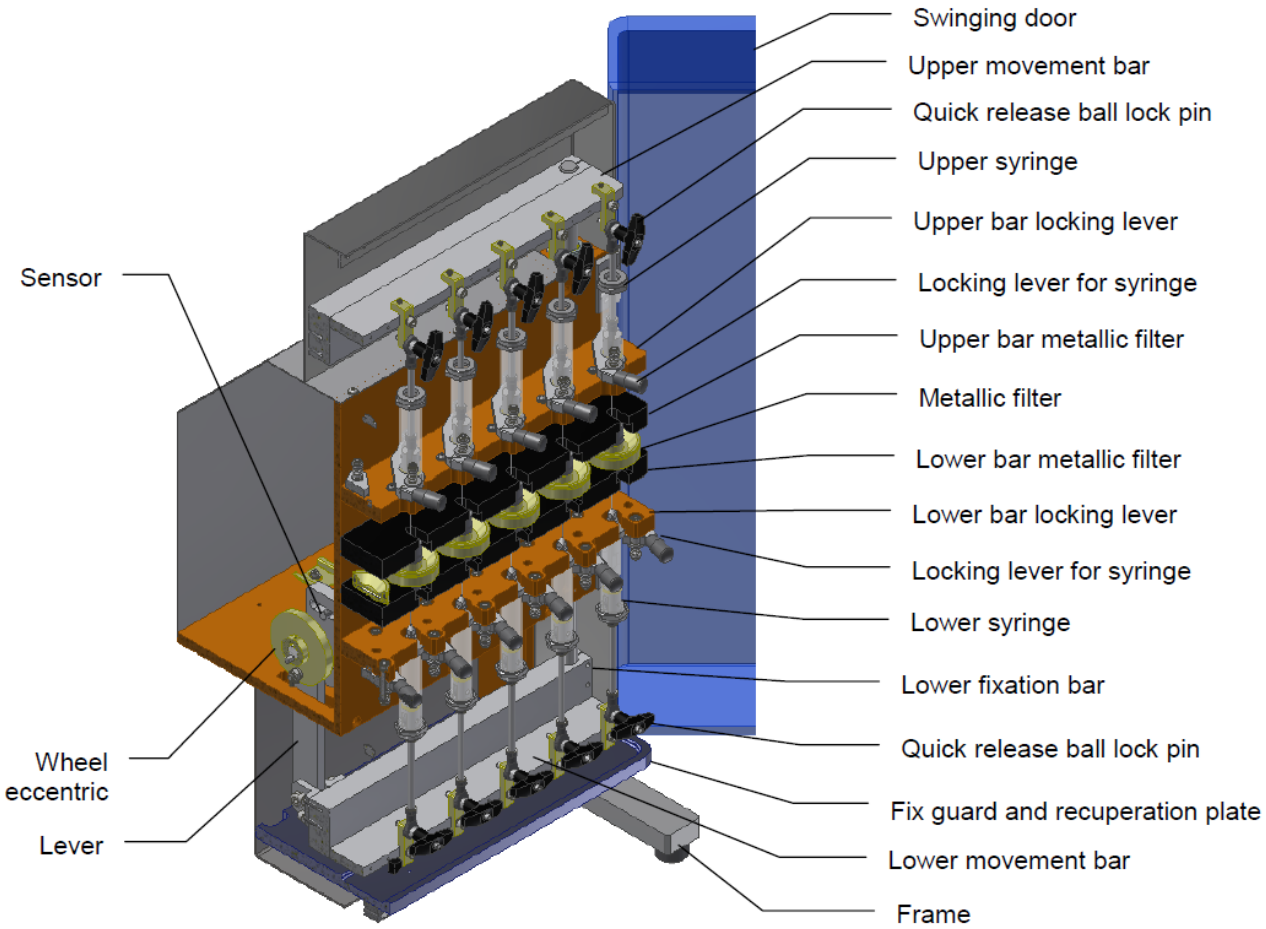
2.2.1 *In situ* extraction

The fundamental principles for the *in situ* extraction is that the water is extracted with a solvent (isopropanol) without opening the filter holder. This can be done using 2 syringes, one filled with 10 mL of isopropanol, one empty, inserted at both ends of the filter holder. Then the filled syringe is pushed, while the empty is drawn, making the solvent flow through the filter containing the collected aerosol. This cycle has to be repeated 60 times to ensure complete extraction of the water from the pad.

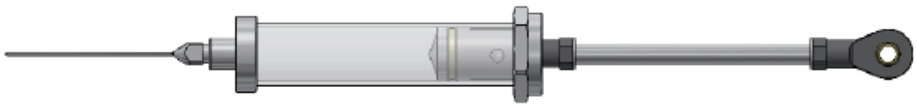
To perform the *in situ* extraction, Philip Morris has developed an *in-situ* extractor, to increase the efficiency of the process. This system is not commercially available for the time being but a system for

testing is available at PMI premises and can be lent upon request. However, the *in-situ* extraction can also be performed manually, as long as the filter pad holder is not opened before extraction.

The picture below gives an overview of the most important components of the *in situ* extractor:



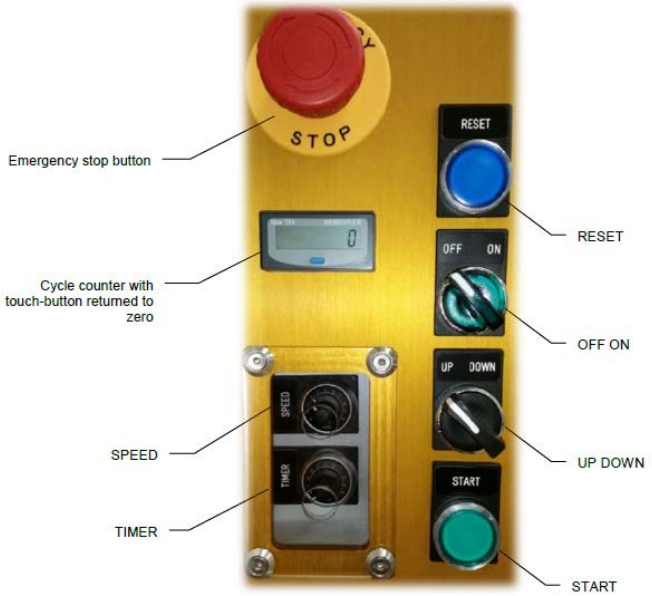
Special syringes have been designed to be used with the *in situ* extractor:



2.2.2 Use of *in situ* extractor

The following step by step instruction describes the procedure to follow using the *in situ* extractor from the end of the aerosol collection after the Cambridge pad has been weighted up to generation of the aliquot to be analysed by GC.

1. Prepare two syringes per Cambridge holder.
2. Arrange the Cambridge holders on the machine, the concave part pointing upwards.
3. Fill half of the syringes with 10 mL of isopropanol.
4. Install the filled syringes on the lower part of the machine by ringing the needle into the hole in the cap of the Cambridge holder and puncturing the septum (be careful not to bend the needles).
5. Lock the body of the syringe by rotating the locking lever to the stop.
6. Lock the plastic balls by using the quick release ball lock pin.
7. On the upper part of the machine, install the remaining syringes.
8. Lock the body of the syringe by rotating the locking lever to the stop.
9. Lock the plastic balls by using the quick release ball lock pin.
10. Close both safety doors.
11. Put the digital cycle counter to 0.
12. Press button RESET for 2 seconds: if the ON / OFF button is turned to ON, the machine starts and the support begins to lead the pistons of syringes.
13. Activate the START button.



14. The extraction is completed once the green START button has turned off and the movement has stopped (after 30 minutes).
15. The number of cycles is recorded by the meter's digital cycle to the right of the machine.
16. Unlock the upper and lower quick release ball lock pins.
17. Push the piston of the upper syringes to the forward position and the piston of the lower syringes to the back position so that the liquid is in the lower syringes.
18. Unlock the locking levers.

19. Remove upper and lower syringes.
20. Remove the metallic filter pad holders.
21. Place the content of syringes in appropriate flasks for the measurement of nicotine and water as per ISO 10315 and ISO 10362 respectively.
22. Clean the syringes with ethanol for next use.
23. Unscrew the needles manually and soak them in an ultrasonic bath for 15 min. Remove the ethanol and dry them in an oven at 60°C night.

3 Reference Documents

- ISO 4387: Cigarettes – Determination of total nicotine-free dry particulate matter using a routine analytical smoking machine)
- ISO 10362: Determination of water in smoke condensates – Part 1: Gas Chromatographic method
- An improved Cambridge Filter Pad Extraction Methodology to Obtain More Accurate Water and "Tar" Values: *In situ* Cambridge Filter Pad Extraction Methodology, D. Ghosh, Beiträge zur Tabakforschung / Contributions to Tobacco Research. Volume 26, Issue 2, Pages 38