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PFS 17.0056 / SUMMARY OF METHODOLOGY AND STATUS REPORT

Summary of the methodology developed and the results obtained following the forensic examination of marks visible on the inside of the plastic caps of BEREG-KIT® bottles.

Status following the examination of 127 questioned bottles and the comparison between them.

by

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Purpose of this report

The purpose of the report is (1) to briefly describe the methodology that has been developed by the Ecole des Sciences Criminelles (ESC), in collaboration with the Laboratoire suisse d'Analyse du Dopage (LAD) to carry out the examination for potential marks inside the plastic cap of closed urine sample bottles from BEREG-KIT® and (2) to provide an overview of the results obtained up to the 30th of November 2017 and the investigative considerations that can be derived thereof. In particular, the results obtained on 127 questioned allowed performing a comparative analysis of the marks observed across bottles. Such an analysis was only feasible after the examination of a reasonably large number of bottles.

This work has been mandated in the context of the following allegations: (1) According to the information made available by the IOC, on one side, it is alleged that the bottle has been initially closed according to regular instructions, then forcibly opened using metallic tools and resealed with the same cap; (2) The alternative proposition is that the bottle has not been subjected to the above-described alleged tampering method, but has been used and closed following regular instructions.

Summary of the developed methodology

The developed methodology aims at assessing if the observations of marks (by their presence and their attributes such as their shape, length, orientation and micro-striae) on the inner side of the plastic cap can help to determine whether or not a bottle has been tampered with as alleged. We were asked to use only non-destructive methods, hence the choice of imaging techniques that can be directly deployed through the transparent cap. This summary is a short outline of the method presented in a longer and more detailed report[1] served on July 27, 2017.

The methodology development consisted of examinations of the marks left under both alleged scenarios – (1) and (2) above mentioned – on a set of unused bottles from BEREG-KIT® produced by Berlinger obtained from anti-doping organisations (ADOs). They correspond in term of glass bottles and caps to the kits used during the Sochi games.

[1] Report on the methodology developed for the forensic examination of marks visible on the inside of the plastic caps of BEREG-KIT® bottles and their potential association with a tampering activity using tools, Report to IOC, July 27, 2017.

A BEREG-KIT® is composed of two bottles (labelled A and B) made of a glass container and a plastic cap (Figure 1a). The glass container (with an ergot on its body) has a glass screw thread starting on its top that finishes with a glass ring moulded with 4 teeth (Figure 1b). The plastic cap contains four components (from the top): a black plastic seal, a stainless-steel spring, a non-magnetic metal ring with teeth and a red plastic ring inserted to avoid the unintentional closure of the bottle (Figure 1c). When closing the bottle, the red plastic ring will be removed so that the cap can be screwed onto the bottle. The stainless-steel spring will push the metal ring on the glass teeth hence sealing the bottle (i.e., blocking the return and opening of the cap). The body of the cap is made of twelve faces (6 flat and 6 curved).

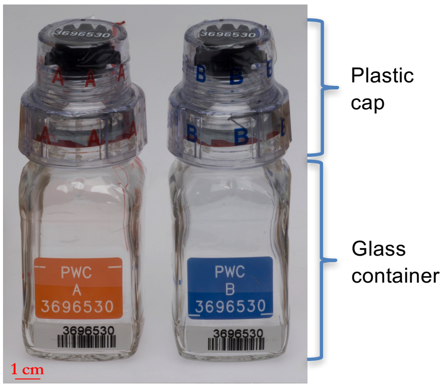

Fig 1a

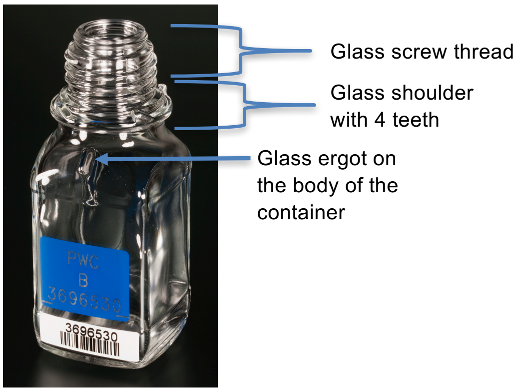

Fig 1b

Fig 1c

Figure 1: Three images of a BEREG-KIT® and its associated components. (a) The two bottles A and B of a BEREG-KIT®. (b) Details of the glass bottle. (c) Plastic cap is shown in its final form with its seal, spring and metal ring maintained in the cap thanks to a thermo-sealed translucent plastic ring.

A diagram of the bottle and its closing mechanism is shown in Figure 2.

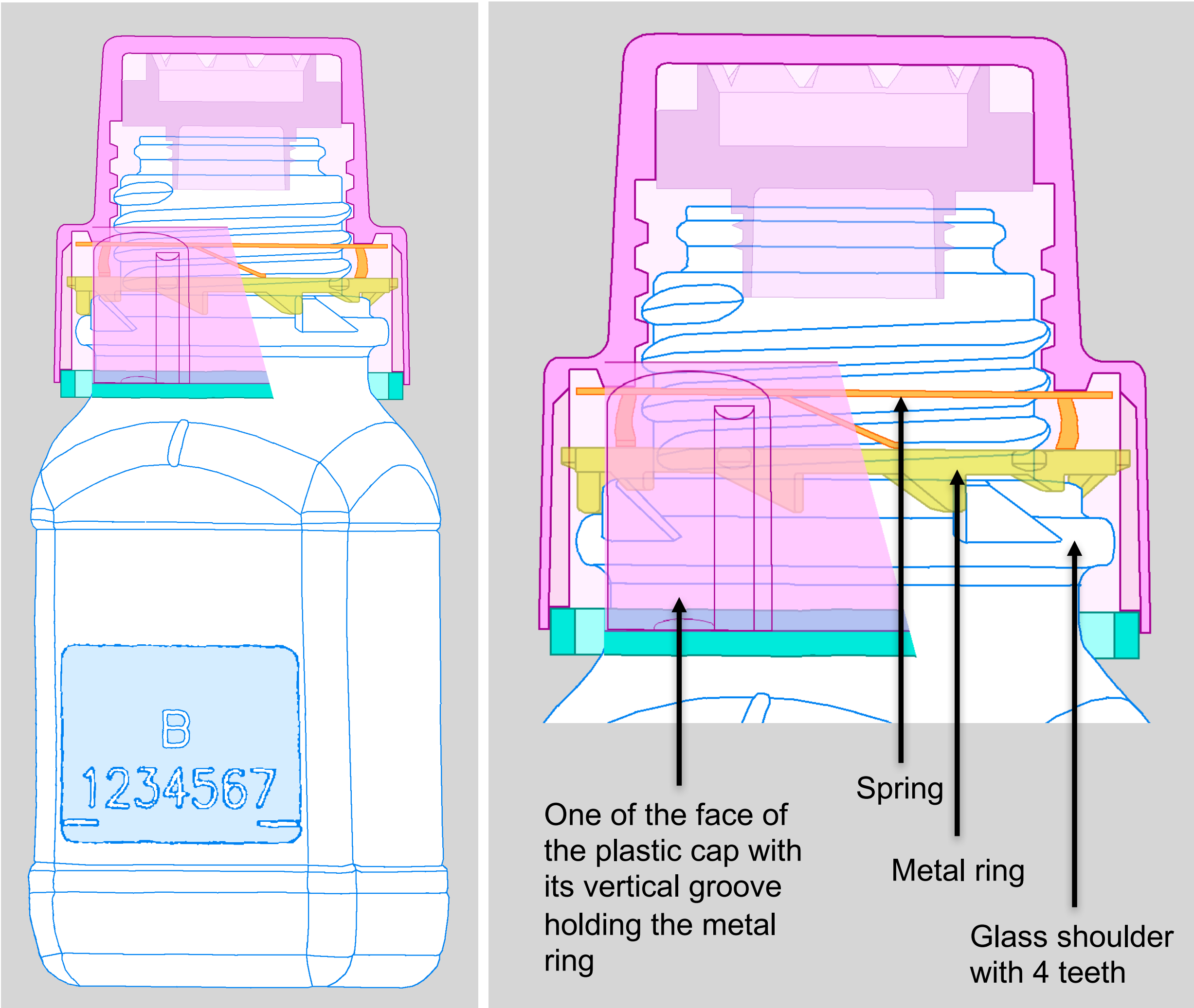

Figure 2: Diagram of the bottle with its components: the plastic cap and its seal (in pink), the metal ring with its teeth (in yellow) pushed down by the spring (in orange) on the reversed teeth of the glass container.

The methodology development took the following steps: (*a*) Design of the photographic setup, (*b*) Investigation of a method allowing the re-opening of closed bottles, (*c*) Examination of marks left on unused and regularly closed bottles and on bottles that had been re-opened, (*d*) Establishment of a protocol for the examination of questioned bottles, (*e*) Quality assurance process and (*f*) Conclusions reached following the forensic examination.

(a) Design of the photographic setup

A photographic setup has been designed to allow the systematic photographic recording, under appropriate lighting conditions, of the bottle itself, then of all 12 faces constituting the plastic cap. The image of the bottle is acquired using a Canon EOS 6D equipped with a EF100mm f/2.8L Macro IS USM lens. The 12 images of the faces are recorded with a SLR Canon EOS 5D Mark III equipped with a MP-E65mm f/2.8 1-5x Macro lens. When marks of interest are observed on any inside face of the cap and when relevant and feasible, macro photographs are taken with a Leica Wild M420 equipped with a Wild 400076 Apozoom 1:6 mounted on a SLR Canon EOS 5D Mark III camera.

The system has been designed to guarantee a full chain of custody (including the recording of detailed metadata associated with each image). It is deployed on an encrypted IT system unconnected to any external network.

(b) Investigation of a method allowing the re-opening of closed bottles

A method was successfully developed to re-open conventionally closed bottles using a technique as close as possible to the technique described in the McLaren report dated 9th of December 2016, p. 82):

> *During follow-up interviews with the IP, Dr. Rodchenkov recalled that he personally witnessed the actual tooling that was used laid out on the workbench of the FSB agent charged with removing the caps. He described instruments, no bigger than a traditional Mont-Blanc pen, and similar to the instruments that a dentist would use in examining teeth, with a handle and thin metallic portion that was bent at various angles.*

It required the design of specific metallic tools that could be inserted between the plastic cap and the glass bottle on at least two positions away from each other (e.g. opposite to each other) to force and lift the metal ring above the glass teeth and hence liberating the plastic cap. Following a series of trials over 6 months with different techniques, including tools of various shapes and materials, an appropriate set of tools has been designed allowing, with some practice, the reopening of closed bottles. In total about 20 different tools were tested under different working conditions (e.g. a bottle held with and without a clamp, fixed on a table, etc.) to retain the one that led to successful opening while leaving a limited number of marks on the inside part of the cap. At that stage we had gained experience at opening bottles (about 20 bottles were studied during that initial phase of trials and errors). Then we started a systematic production and acquisition of marks obtained under controlled conditions (section *c* below). The instruments retained at this point were surgical tools with a circular section ending at about 0.45 mm with a pointy tip. The shape of the tool and its tip has been adapted to facilitate the entrance between the glass container and the plastic cap and its interaction with the metal ring to push it up.

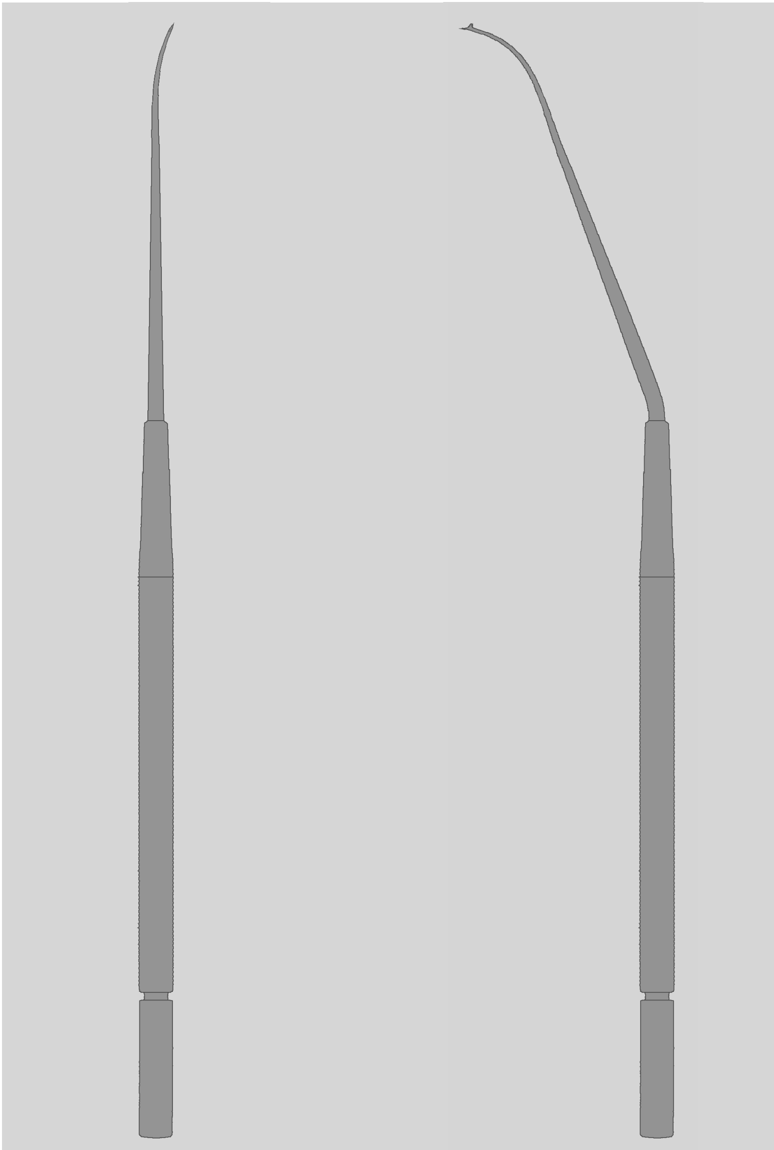

Figure 3: Sketches of the designed tool. It is shown from a top view on the left and from a side view on the right.

We noted that the degree of initial closure of the bottle has an impact on the level of difficulty to re-open it. A bottle is fully closed with a maximum number of clicks of 15 (we called that point “15 clicks” referring to the number of metallic clicks obtained to close the bottle to that point). An additional increment towards closing is possible when the metallic teeth come up the glass teeth (degree of closure 15+). A closure of 12 clicks corresponds to a full turn (360 degrees) of the cap once it is inserted into the glass container screw. 15 clicks amount to one turn and a quarter, as each click amounts to 30 degrees. On a closed bottle, the measure of the level of screwing that the cap received (in degrees) allows to determine the number of clicks engaged to close the bottle.

The more the bottle is closed, the smaller the space between the glass container and the plastic cap becomes. In order to successfully open such a bottle, more strength and movements between the cap and glass are required when using the instruments, leaving more marks. When the bottle is closed less tightly (with for example 10 clicks), the space left between the glass container and the plastic cap is larger which eases the opening with our tools, leaving fewer marks associated with that tampering activity. In other words, the tighter a bottle is initially closed, the larger the number of marks left by the re-opening tools will be. The glass ergot on the body of the container also reduces the space available to introduce tools between the translucent ring and the glass container. We also noted that our ability to re-open bottles improved with the number of bottles opened. This increased ability meant that the number of marks left by the tools reduced.

(c) The examination of marks left on new and regularly closed bottles and on bottles that had been re-opened

Equipped with the designed tools and using the opening process, 22 bottles, obtained from Sochi compatible kits were investigated and these experiments were documented in the methodology report served in July 2017. These bottles have been used to simulate both activities; hence to produce marks for which production mechanisms can be established. Marks consecutive to the manufacturing process were distinguished from marks due to the regular usage (closure) of the bottle respectively from marks that were left by the tools that were used to re-open the closed bottles.

This work has been helped and informed by two visits: (a) The understanding of the mechanical methods by which the bottles can be opened and their associated marks was greatly helped by a visit made on the 24th of March 2017 to the forensic expert who prepared the forensic report related to the McLaren inquiry (*Examination relating to urine sample bottles of BERLINGER* – EDP0902.pdf); (b) A visit at the factory Berlinger Special AG (Ganterschwil, Switzerland), carried out on the 19th of May 2017, helped to understand the manufacturing process and its associated marks.

The term “marks” hence refers to all extraneous impressions in the inside of the plastic cap (scratches and marks visible on the smooth inner surface), on the metal ring or on the translucent plastic ring of the cap. They have been classified according to the following main classes:

***F* marks** that are typical of those observed consecutive to the manufacturing process either at Berlinger or its suppliers.

***U* marks** that are typical of those observed on the inside of the cap and that are left either by the spring, the metallic ring or the glass container when the bottle is regularly closed.

***T* marks** that are typical of those observed consecutive to a tampering activity as described above. They can be left by the designed tools. Other *T* marks are due to the movement of the metal ring when forced up, or the unscrewing of the cap.

The bottles were examined after unpacking them from their kit. The marks present on the bottles at that stage were systematically recorded. The bottles were then closed and re-examined to detect the marks consecutive to their closing. Then, 11 bottles were forcibly opened using the designed tools and reclosed to investigate the marks associated with the use of the tools. Subsequent to the delivery of the methodology report, an additional 10 bottles were re-opened by the forensic examination team using the same process. Altogether, the re-opening experiments were carried out on a total of 21 bottles initially closed between 6 and 11 clicks. That level of closure was chosen in order to lessen the number of *T* marks. Indeed, when the bottle is fully closed (e.g. at 15 clicks), the space left for the tool is reduced hence increasing the number of marks that will be left. By concentrating on bottles closed at a lower number of clicks, we guarantee that we have operated at the boundaries where the marks due to the tools are expected to be at their lowest. If these marks can be detected and characterised, the detection of marks left on bottles initially closed more tightly can be achieved as well. It is worth noting that the bottle is considered as sealed (meaning that the contained urine will not leak) when closed with at least 5 to 7 clicks (according to the manufacturer).

All these marks produced under controlled conditions have been characterised in terms of their position on the inside of the cap, their orientation (e.g. horizontal, vertical, oblique) and shape (e.g. texture, perceived depth and presence of striae). It has allowed the constitution of a structured and searchable corpus of marks of known status produced under controlled conditions. More than 1500 marks have been characterised and served as a reference set of images for the forensic examiners. Since *F* and *U* marks can be distinguished from *T* marks by their positions and attributes, we were satisfied that a forensic examination carried out with this protocol on questioned bottles could help to guide as to whether or not the bottle had been tampered with or closed regularly.

(d) Protocol established for the examination of questioned bottles

An examination procedure has been put in place to examine each bottle individually. The forensic examination team carried out the following steps:

1. The bottle is placed on the photographic bench and photographed. The photographic apparatus, placed above the bottle, allows the simultaneous recording of the cap with its serial number and the container serial numbers. This is achieved by using a mirror placed at 45 degrees on the side of the bottle.
2. The 12 faces (named A to L) of the plastic cap are photographed under appropriate and controlled lighting conditions.
3. The images obtained are examined and assessed by the forensic examination team and the visible marks are classified as *F*, *U* or *T* marks. Note that when working on bottles of known status, the nature of the marks is established based on the knowledge of the sample and of the experiment carried out (closure, opening and re-closure). **For the bottle submitted (of questioned status), the real nature of any observed marks – i.e., the exact mechanism whereby the marks were produced – is unknown. That being said, we still used the labels (*F*, *U* or *T*) for the observations made on the plastic cap.** These labels do not mean that the nature of the marks is definitively established, but it is that their attributes (size, position, shape and direction) were compatible with what we have seen on marks of known status. In other words, during

the characterisation of the marks left on the inside of the plastic cap of the questioned bottle, the labels assigned to observed marks only indicate that their source is presumed and that their attributes are compatible with observations made in controlled conditions.

4. When the screening images showed the presence of so-called *T* marks, they have been recorded, when feasible and relevant, under appropriate lighting conditions at high magnification (macro photographs).
5. The acquired photographic material is assessed and the examination team reaches a conclusion.
6. The case is then peer-reviewed by a second forensic team. The peer review process is blind, meaning that the reviewers have no knowledge of the conclusion reached by the examination team until they reach their own conclusion.

(e) Quality assurance process and use of control samples

The bottles to be examined have been grouped into batches. Each batch contains between 36 and 54 bottles under investigation and a series of control samples. These controls are 4 positive/negative controls (bottles used to develop the methodology of known status), 4 single blind samples and 3 to 5 double blind samples (bottles chosen by the IOC coming from the Sochi games). During the examination of a batch, the identity of the single blind bottles is known by the LAD, but not to the forensic examination teams. The identity of the double-blind samples is unknown to all actors except the IOC. Each batch is first processed by the examination team and then transferred to the second team of peer-reviewers. The team of peer-reviewers conducts an independent assessment based on the photographs delivered by the examination team. For each case where differing conclusions have been reached, or the retained marks and associated annotations differ, or additional images are required, a consensus meeting is set up to discuss the case. The nature of the bottles corresponding to the single-blind samples is only disclosed at the end of the peer-review process. The identity of the double-blind samples is uncovered once all the reports associated with the batch have been delivered.

(f) Conclusions reached following the examination of each bottle

Recall that the purpose of the examination is to help assess whether or not the submitted bottle has been subjected to the above-described tampering process. Regarding the examined bottle, the results of the examination performed on the inside of the bottle cap will be assessed given the following two alleged propositions:

(1) either the bottle has been initially closed according to regular instructions, then forcibly opened using metallic tools and resealed with the same cap;

(2) or the bottle has not been subjected to the above-described alleged tampering method, but has been used and closed following regular instructions without any wrong doing.

The forensic examination aims at assessing if the observations of marks (by their presence, position and attributes) on the inner side of the plastic caps can guide towards the first or the second proposition. If guidance can be offered based on these marks, the strength associated with the observations with regards to the two above competing proposition will be assigned. In the context of this mandate, only the above-described tampering method (or similar operations with tools) has been investigated and not all conceivable usages of the bottles or actions that may facilitate its opening. If any of the information given to us were to change (e.g., a new way of re-opening the bottles or information on the tools), our conclusions may need to be revised. Following the forensic examination of a bottle, three possible conclusions can be reached, depending on the observations made on the inside of the plastic cap. They are detailed below.

Case	Observations	Conclusion
Case 1	**Multiple so-called *T* marks** alongside with *U* and *F* marks	These results are **more than a 1000 times more probable** if the bottle has been initially closed, then forcibly opened and resealed with the same cap rather than if it has been used and closed following regular instructions without any wrong doing.
Case 2	**One or more isolated so-called *T* marks** are observed, alongside with the expected *U* and *F* marks.	The results are **neutral**, meaning that they provide no more weight for one proposition versus the other.
Case 3	**No so-called *T* marks** have been observed, but only *U* and *F* marks.	The observations are **more than 10 times more probable** if they are consecutive to a normal closing of the bottle rather than if there was tampering.

Each case is explained in more details below:

Case	Comment
Case 1	On the questioned bottle, on the inside of its plastic cap, **multiple so-called *T* marks** are observed, alongside with the expected *U* and *F* marks. Multiple so-called T marks have been observed at locations around the cap that are in line with the positions that would be adequate to facilitate the opening of the bottle by lifting the metal ring. The faces showing *T* marks are far on each side of the bottle. We have never observed empirically such marks on bottles that have been regularly closed. But, given the limited number of bottles (22 in total) we examined during the development of this methodology, we do not claim that it is impossible to make such observations under the proposition of normal use of the bottle. On the other hand, these results are in line with what has been empirically observed when we tampered with test bottles. The nature of the marks, their shape and compatibility with the working of metallic tools at multiple locations allow us to conclude that these results are more than a 1000 times more probable if the bottle has been initially closed, then forcibly opened and resealed with the same cap rather than if it has been used and closed following regular instructions without any wrong doing. Using the verbal equivalents of our institution[2], this weight corresponds to the category 1000 to 10000. The observations thus provide **very strong support** for the proposition that the bottle has been tampered with as alleged compared to the proposition of normal use. The strength of the observations is related to the number of marks observed on normally used bottles and an assessment of the mere possibility to create them through normal usage.
Case 2	On the questioned bottle, on the inside of its plastic cap, **one or more isolated so-called *T* marks** are observed, alongside with the expected *U* and *F* marks. The observation of a *T* mark or a few *T* mark(s) in isolation (on one face or two adjacent faces) is an observation that we have not made during our tests, neither on normally closed bottles nor on bottles that we had tampered with. This observation raises the possibility of tampering but it cannot be assessed against the alleged tampering proposition. This is because these observations are also absent from the corpus of *T* marks that we produced under controlled conditions. The observations may suggest that another tampering method has been used, but it may also be because of some other unknown phenomenon. Therefore, with regards to the specific propositions at hand, the results are **neutral**, meaning that they provide no more weight to one proposition versus the other.
Case 3	On the questioned bottle, on the inside of its plastic cap, **no so-called *T* marks** have been observed, but only *U* and *F* marks. Observing only *F* and *U* marks is what we would expect if the bottle has been used and closed following regular instructions without any wrong doing. Indeed, such observations are what we have seen and documented on bottles that have been closed regularly. When tools were used to forcibly open the bottles, additional so-called *T* marks are generally left. None of them were seen in this case. Due to the limited number of bottles that we re-open under control conditions (11 in total), we do not claim that it would be impossible to carry out such a tampering process without leaving any recognizable *T* marks. But, given our experimental results, we are of the opinion that the observations are more than 10 times more probable if they are consecutive to a normal closing of the bottle rather than if there was tampering. Using the verbal equivalents of our institution, this weight corresponds to the category 10 to 100. The observations thus can be said to provide **moderate support** for the proposition that the bottle has been closed regularly, rather than for the proposition that the bottle has been forcibly opened.

[2] R. Marquis, A. Biedermann, L. Cadola, C. Champod, L. Gueissaz, G. Massonnet, W.D. Mazzella, F. Taroni, T. Hicks, Discussion on how to implement a verbal scale in a forensic laboratory: Benefits, pitfalls and suggestions to avoid misunderstandings, Sci. Justice, 56 (2016) 364-370

State of the results obtained on the questioned bottles as of the 30th of November 2017

Conclusions reached following the examination of three batches

The forensic examination of the batches containing the questioned bottles started on the 15th of August 2017, with the forensic examination of about 4 bottles per day. The daily work has been organised in 2 shifts of 8 hours. The first team of forensic examiners is composed of 10 staff members. The second team of peer-reviewers is composed of 4 staff members. By the end of October 2017, the forensic examination had been carried out on three batches for a total of 163 bottles. These consisted of 127 questioned bottles, 12 positive/negative controls and 24 single/double blind samples. The conclusions reached at the examination of the 127 questioned bottles break down in Table 1.

Batch	Case 1: Multiple *T* marks observed	Case 2: Isolated *T* mark(s) observed	Case 3: No *T* marks observed	Total
Batch 1	10	7	19	36
Batch 2	9	2	26	37
Batch 3	6	9	39	54
Total	25 (20%)	18 (14%)	84 (66%)	127

Table 1: Conclusions reached by the forensic examination teams after the examination of 127 questioned bottles.

Overall, 20% of the questioned bottles bear multiple *T* marks, 14% showed isolated *T* marks, the remaining 66% showed no *T* marks.

All of the positive/negative controls have been properly classified. Among the 24 single/double blind samples, 22 were concluded as bearing no *T* mark, whereas on two bottles from the first batch we concluded to isolated *T* mark(s). They are considered as correctly classified as well.

Distribution of the conclusions as a function of the dates of delivery at the Sochi laboratory

Each questioned bottle comes with information regarding its date of delivery at the Sochi laboratory. The graph below (Figure 4) shows how the conclusions for each bottle distribute over collection time. We note that the first bottles where a conclusion of multiple *T* marks was reached have been delivered on the 6th of February 2014. Then bottles associated with a conclusion of multiple *T* marks or isolated *T* mark(s) are distributed over the entire timeframe of the delivery period until the 24th of February 2014.

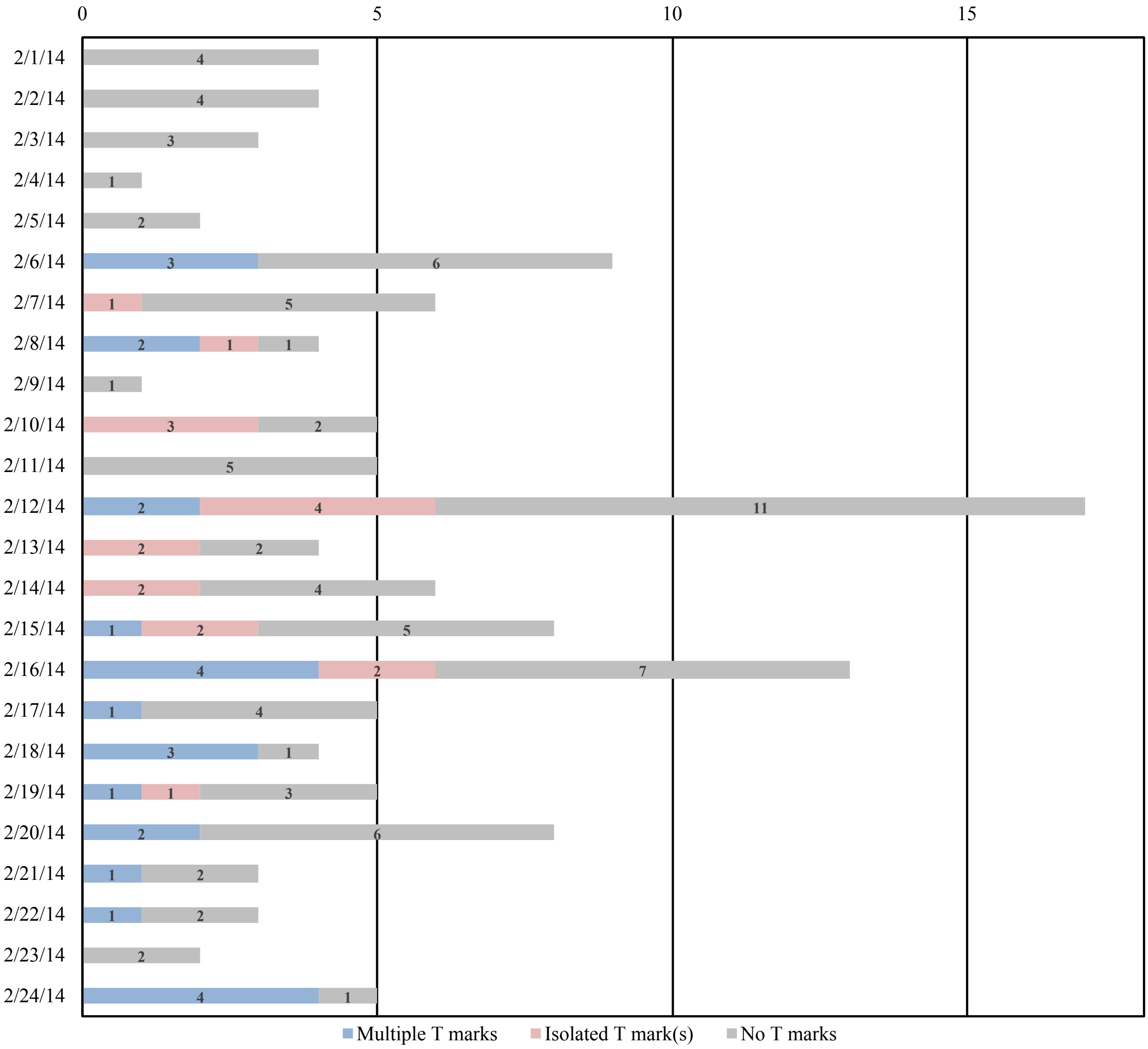

Figure 4: Distribution of the bottles according to their respective conclusions as a function of their date of delivery at the Sochi laboratory (from February 1st 2014 to February 24th 2014).

Marks observed and characterisation of the opening method if bottles had been tampered with as alleged

A first observation, in line with the observations made on the bottles closed under controlled conditions, is that the *U* marks are located at specific locations on the inside of the plastic cap. They are the consequence of the movements of the spring, of the vertical movements of the metal ring in the groove of the cap or of the horizontal movements of the cap when rubbed on the glass shoulder bearing the glass teeth. *U* marks are then consecutive to the mechanical movements produced during the closing procedure. A typical illustration of these *U* marks is shown in Figure 5.

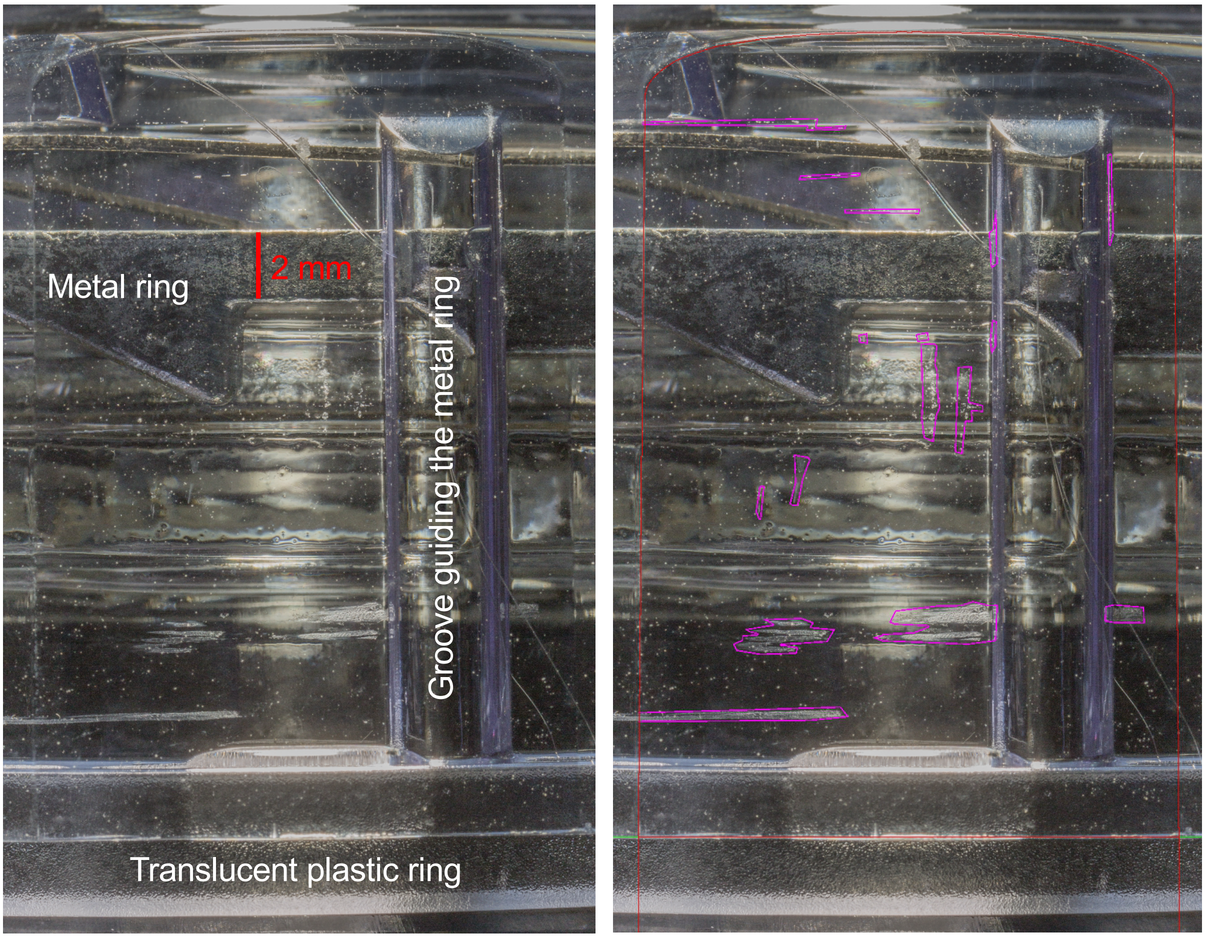

Figure 5: Photograph of one of the flat faces showing vertical and horizontal U marks observed on one of the 24 single/double blind samples. On the left, the face is shown without annotation of the marks. On the right, the U marks are outlined in magenta. The red frame outlines the sides of the face. Note the presence of the vertical groove on the cap that guides the metal ring in its vertical movements on the right side of the face. The translucent plastic ring sits at the basis of the cap. The width of the metal ring is shown with a red segment of 2 mm.

Figure 6 shows the overlay of all the *U* marks annotated on the 12 faces (distinguishing the flat faces and the curved faces) of the 24 single/double blind samples after their examination. Generally, more marks were observed on flat faces compared to curved ones.

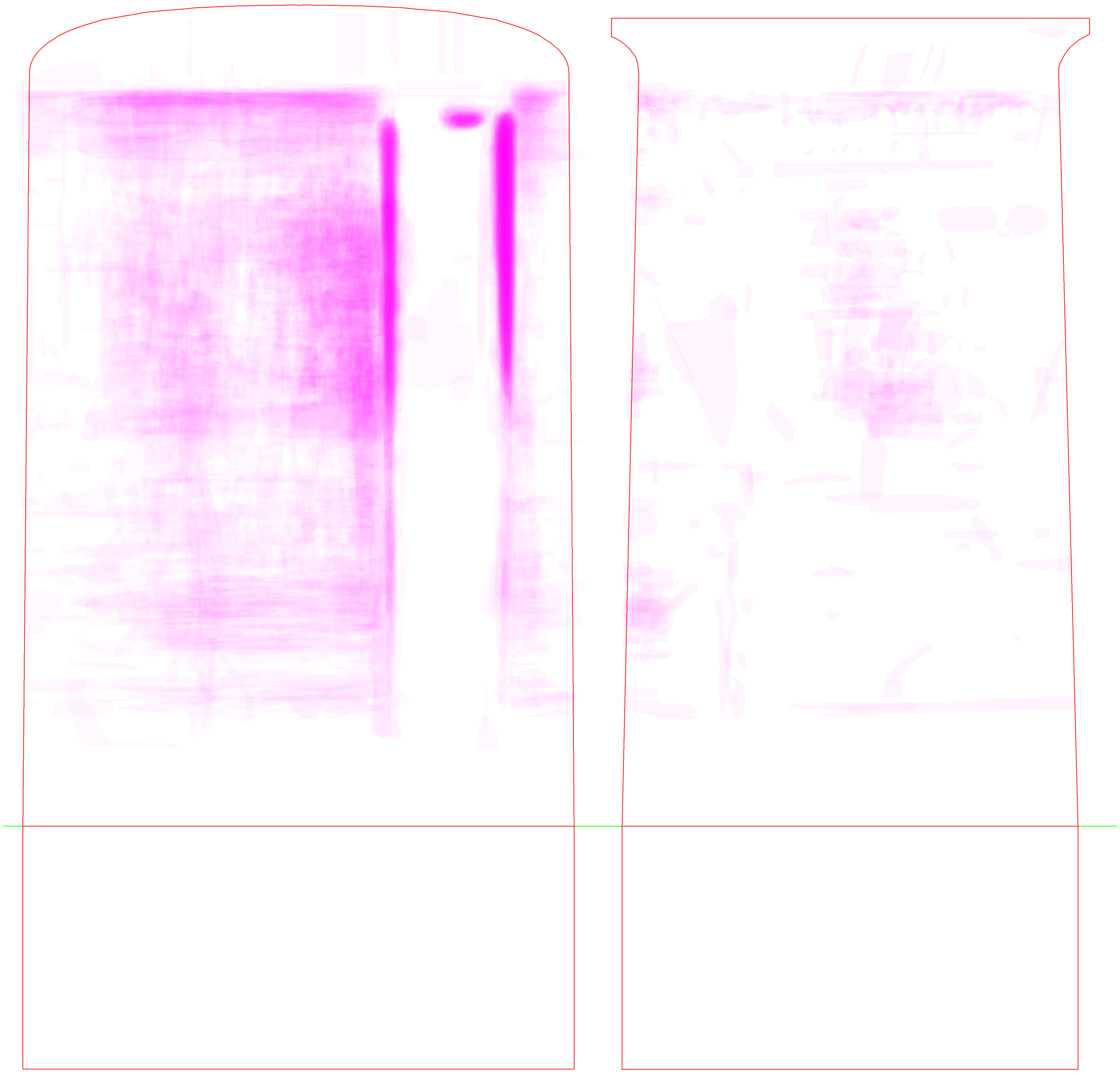

Figure 6: Representation of the spatial distribution of all the U marks observed on the faces of the 24 single/double blind samples. They are presented as an overlay between all the faces with marks respectively on 141 flat faces (left) and 92 curved faces (right).

Using a similar overlaying process, the spatial distribution of so-called *T* marks observed on the 25 bottles concluded "multiple *T* marks" is shown in Figure 7.

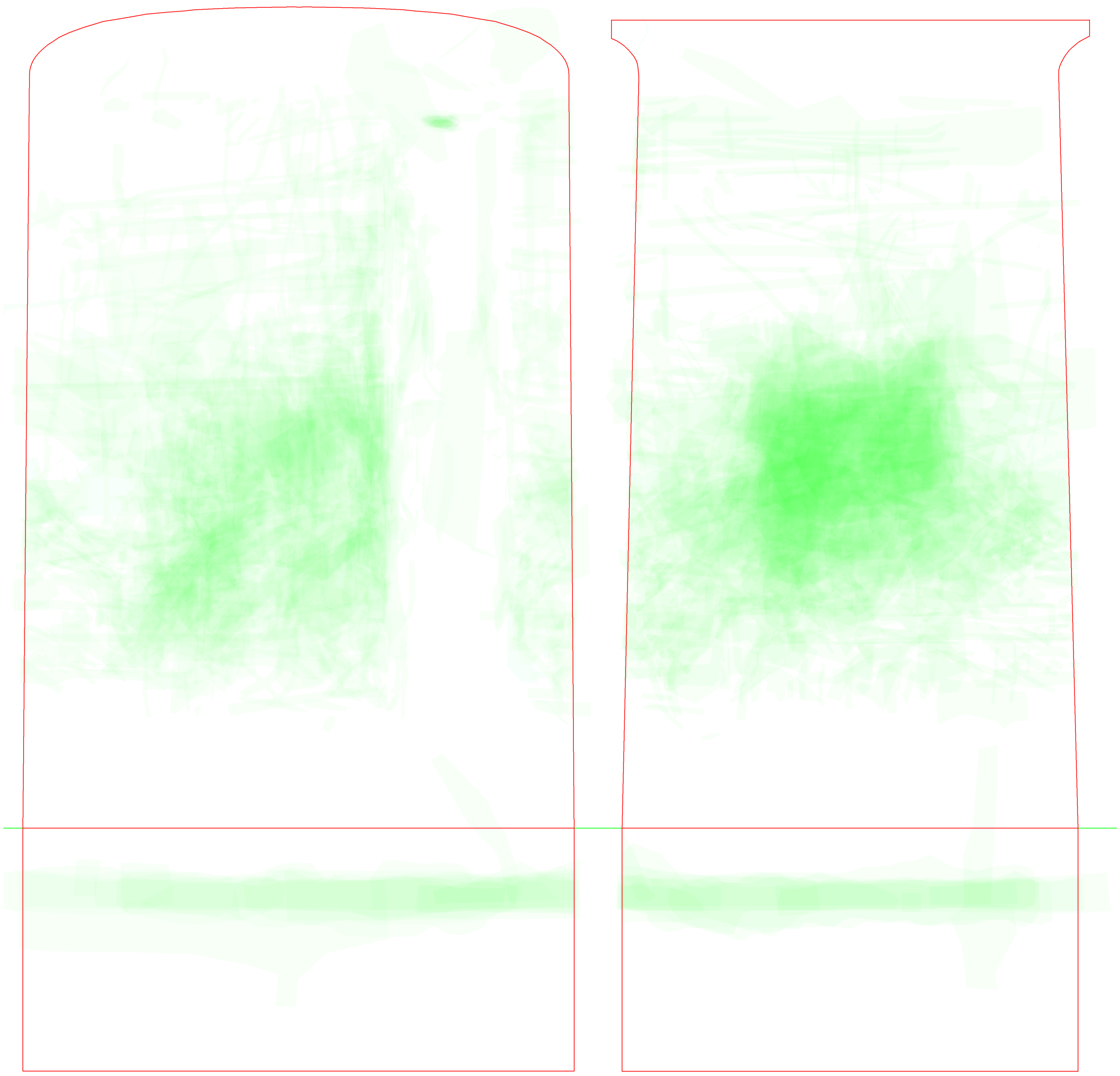

Figure 7: Representation of the spatial distribution of all the so-called T marks (overlaid) observed on all the faces of the 25 bottles for which a conclusion of "multiple T marks" has been reached. It aggregates T marks on 115 flat faces (left) and 97 curved faces (right).

The so-called *T* marks are located either close to the middle of the face, close to the metal ring or on the inside of the translucent plastic ring at the basis of the plastic cap. These observations are in line with the location and type of *T* marks that were produced when opening bottles using our designed metallic tools. They can be distinguished from the *U* marks shown collectively in Figure 6.

If we assume that these 25 bottles have been opened as alleged, and based on our observations, we are of the opinion that the tools that have been used to forcibly open them are leaving similar patterns to the tools we designed and have been used in a comparable manner. These tools are compatible with the description provided by Dr Rodchenkov. They are thin points with a round (or oval) cross-sectional shape and a specific bend to facilitate their entry between the glass container and the plastic cap. To gain access to the metal ring and lift it up, the tool is first introduced sideways in order to pass the glass shoulder, then twisted upwards to reach the metal ring and push it up, with force, in order to liberate the closing mechanism. The above movements needed to re-open a bottle are illustrated in Figure 8 and Figure 9.

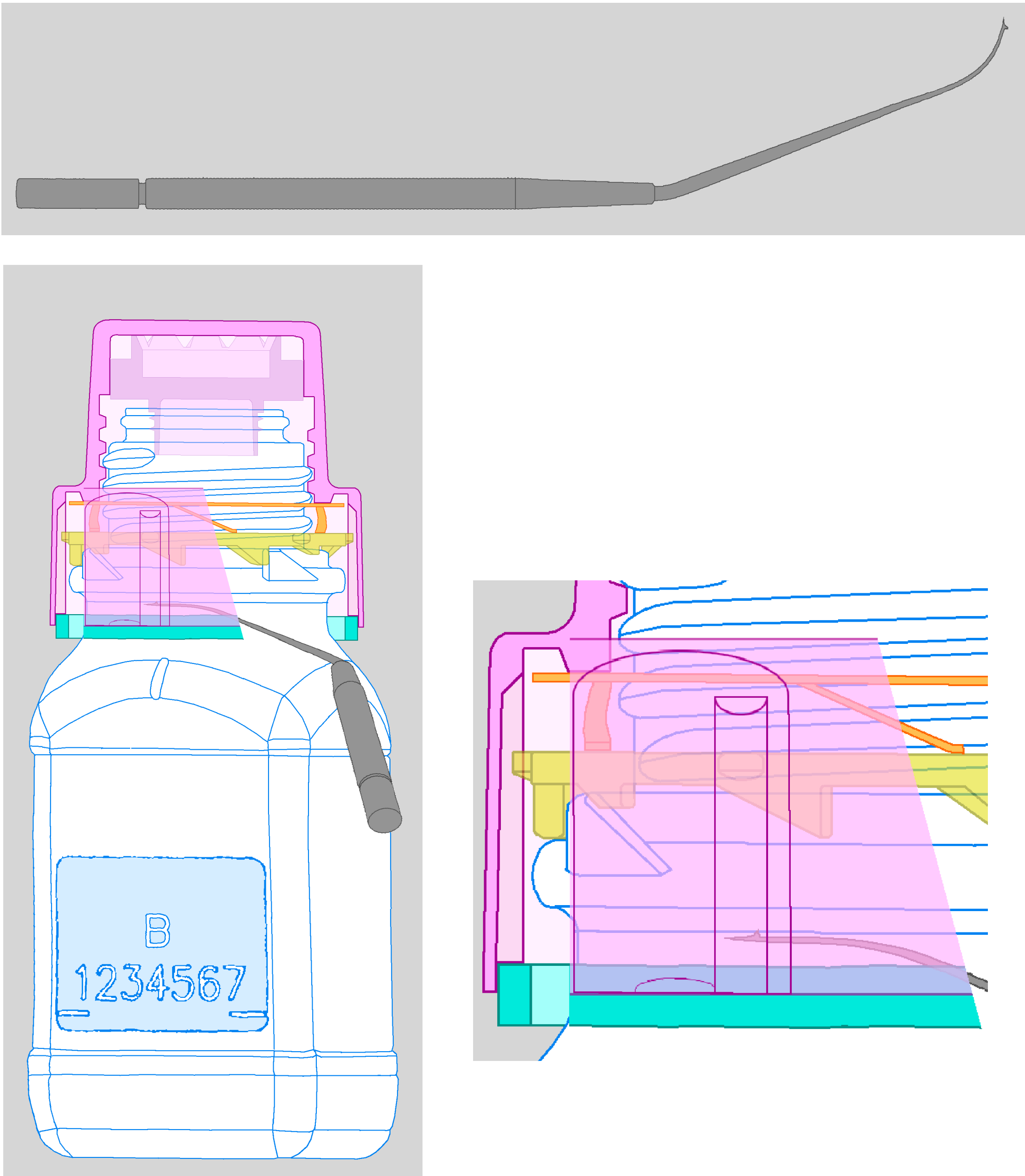

Figure 8: Top: Illustration of the designed tool. Bottom: Representation of the bottle, the designed tool (in dark grey) placed for its first introduction sideways below the glass shoulder. An enlarged view is shown on the right.

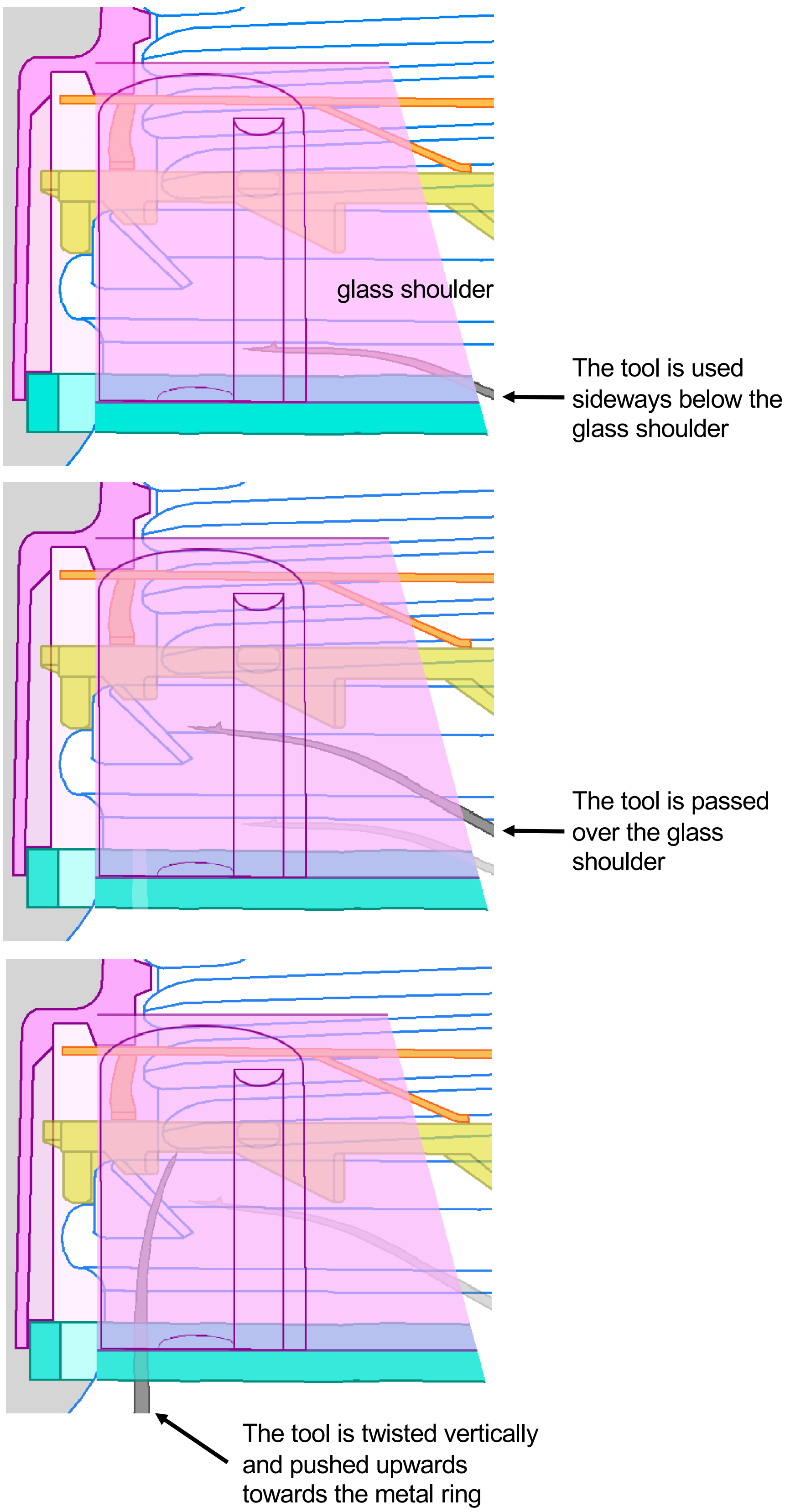

Figure 9: Top: The tool is introduced sideways below the glass shoulder. Middle: The tool is then passed over the glass shoulder. Bottom: The tool is finally twisted by 90 degrees and moved up in order to reach the metal ring that will be pushed up.

The tool can scratch the inner part of the cap at several moments. First, the tip of the tool may scratch the inside part of the cap when making its way over the glass shoulder. It will leave horizontal marks that can be distinguished from *U* marks. Once the tip of the tool passes over the glass shoulder (in an oblique, close to horizontal movement), it needs to be twisted vertically. At that moment, the tool is then located where the space between the inner side of the plastic cap and the glass shoulder is minimal. The twisting movement required to put the tool vertically will force the tool to rub the plastic surface and leave marks that have specific oblique orientations and striations. Examples of the above marks on a bottle that was closed and re-opened with our tools are documented in Figure (a) and Figure (b).

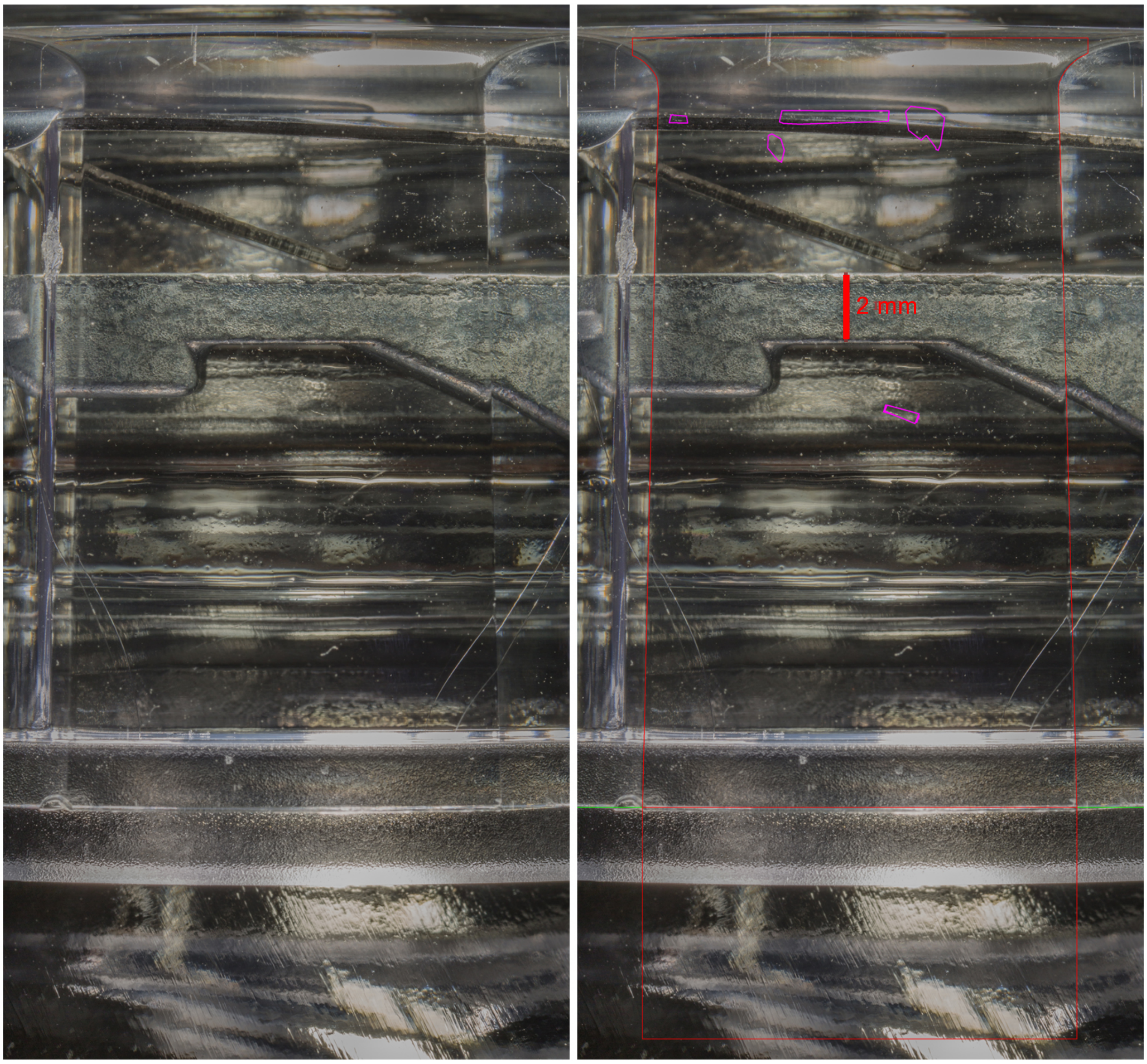

Figure 10a: U marks (in magenta) observed following regular closure of the bottle, on the right without annotation and with annotations on the left. The width of the metal ring is shown with a red segment of 2 mm.

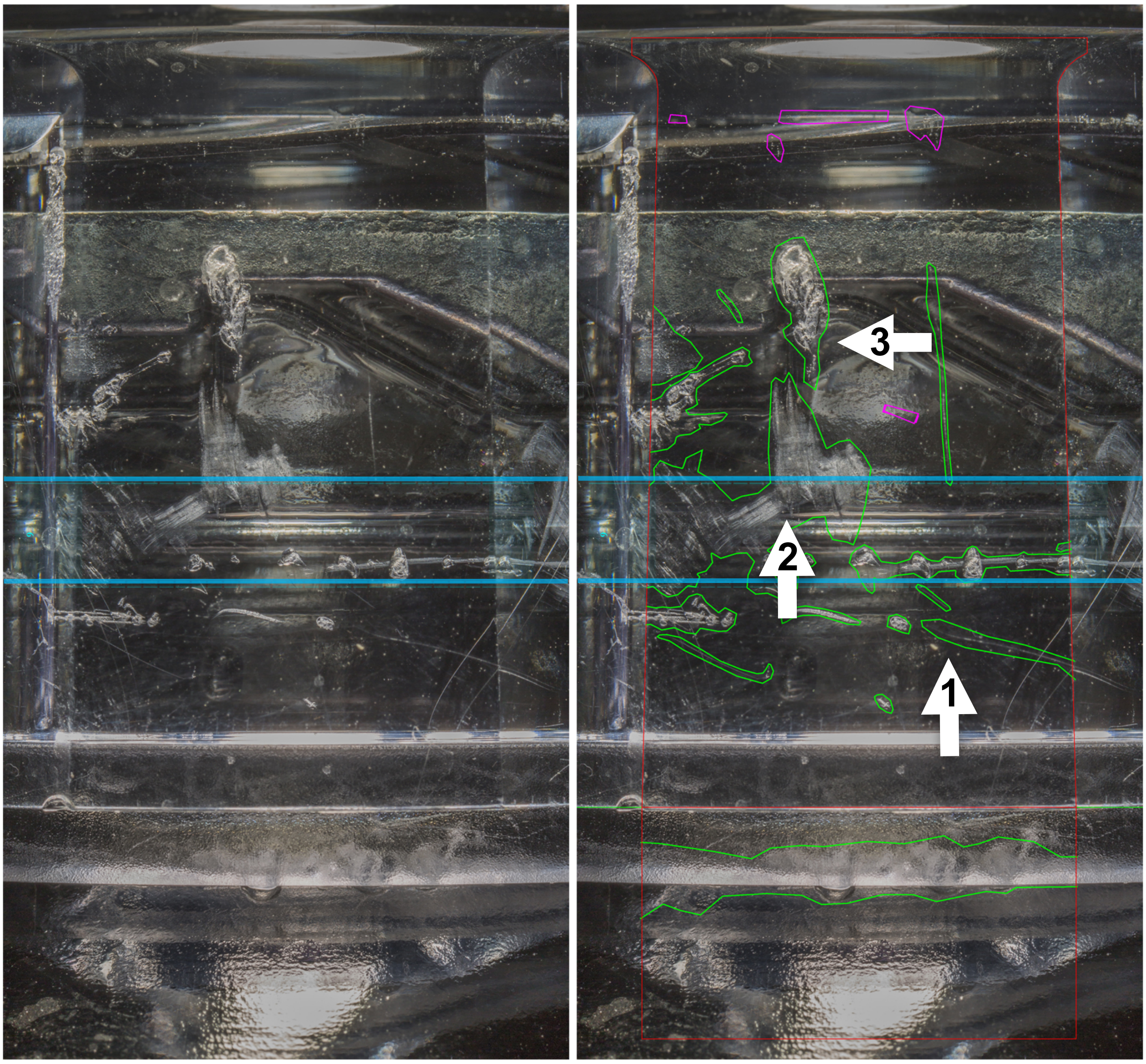

Figure 10b: U marks (in magenta) observed following regular closure, re-opening using our tools and re-closing. T marks so produced are shown in green. The numbered arrows are pointing on a close to horizontal T mark (1); an oblique T mark (2) and a vertical mark (3), all consequences of the introduction of the tool. The horizontal blue lines give the position of the glass shoulder before the bottle had been opened.

Figure 11 shows the overlaid representation of all the faces showing these oblique *T* marks, observed on 15 bottles out of the 25 for which a conclusion of "multiple T marks" has been reached.

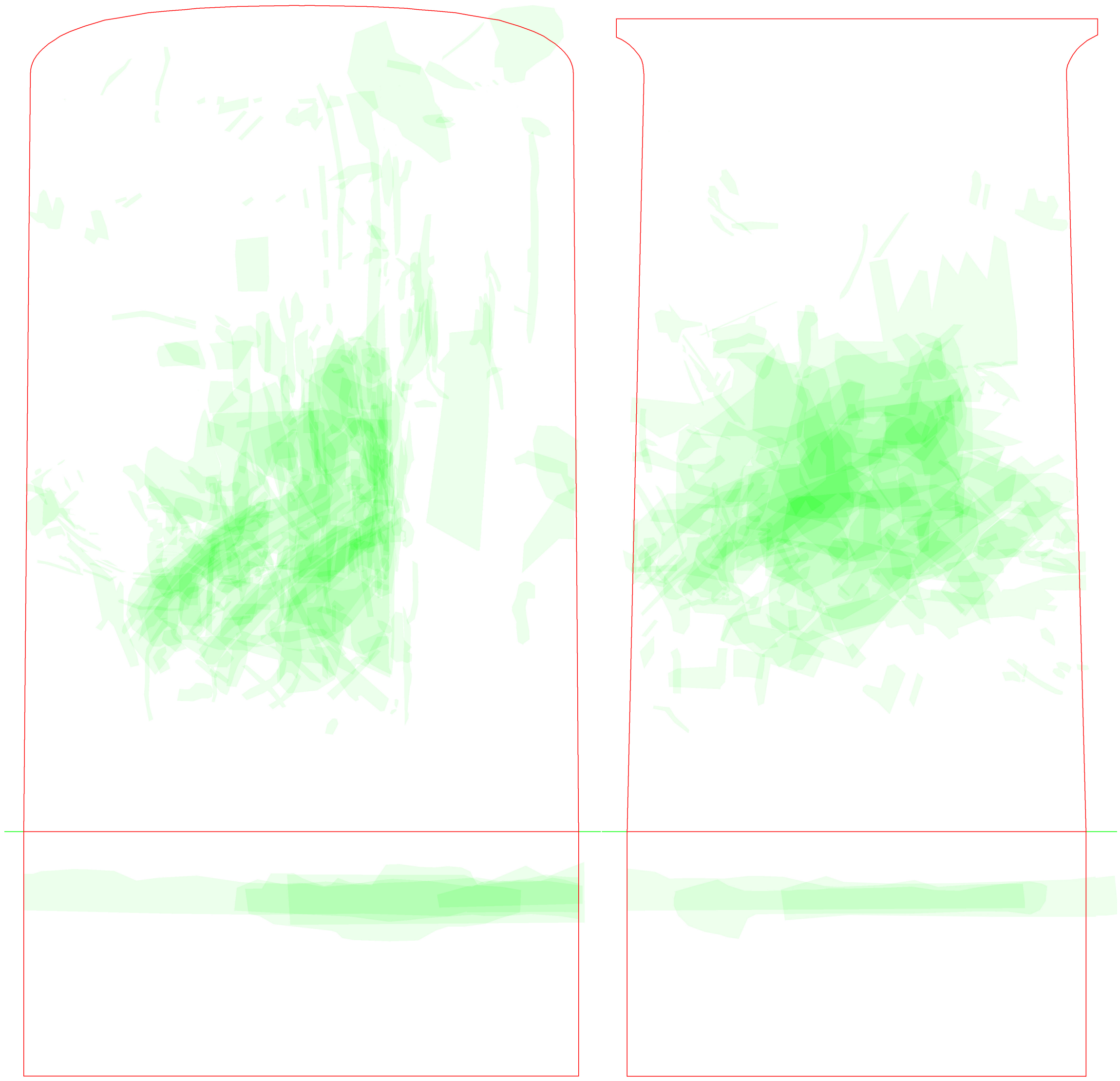

Figure 11: Representation of the spatial distribution of all oblique T marks (overlaid) observed on the faces of 15 bottles out of the 25 concluded with multiple T marks. It represents the aggregated oblique T marks on respectively 20 flat faces (top) and 16 curved faces (bottom).

These oblique marks are positioned at the point of contact between the glass shoulder, the tool and the inside of the plastic cap. Hence, these marks give spatial information that can be used to estimate the level of closure of the bottle prior to its opening. Indeed, as illustrated in Figure 12, there is a significant difference in the relative position of the glass shoulder and the bottom of the cap between a fully closed bottle and a bottle closed with less clicks. A fully closed bottle will show a larger distance between the glass shoulder and the bottom of the plastic cap.

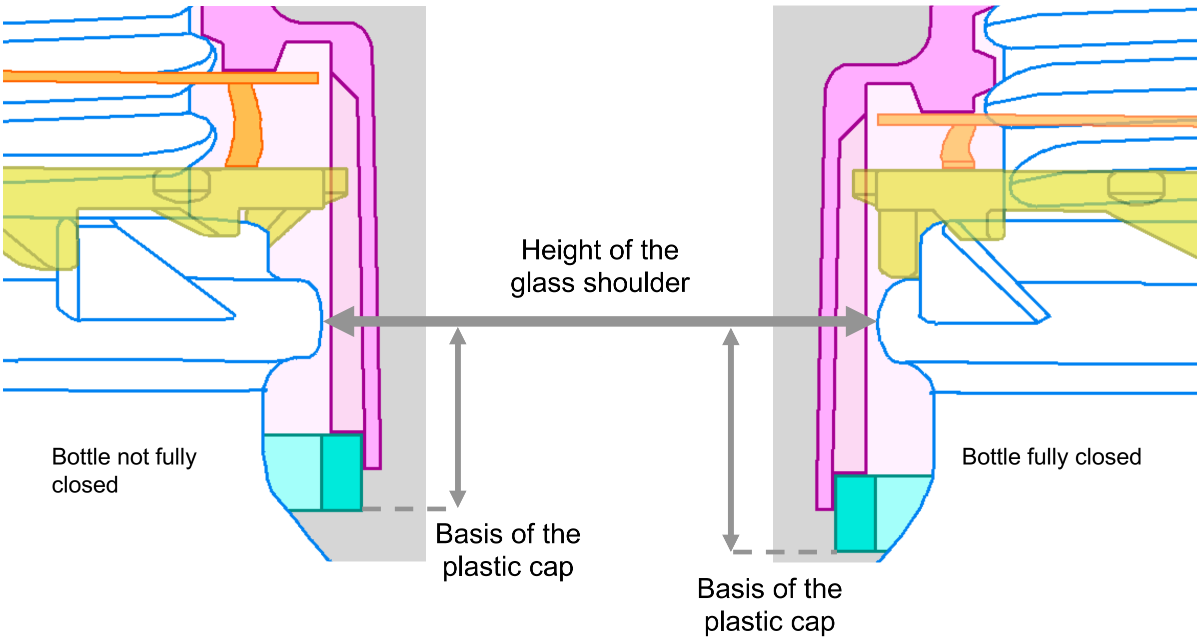

Figure 12: Illustration of the difference in the position of the glass shoulder relative to the basis of the plastic cap between a bottle not fully closed (left) and a bottle fully closed (right).

The position of these oblique *T* marks gives the possibility of locating the position (or height relative to the basis of the cap) of the glass shoulder. That position is directly linked to the degree of closure (expressed in clicks).

Without prior knowledge of the degree of closure, three examiners independently assessed the heights of the glass shoulder (that is linked to the number of clicks). The assessment of the degree of closure of the bottle is carried out by placing the boundaries of the glass shoulder on the relevant marks, directly on the images, when all the faces showing *T* marks are placed in line. The determination made on a controlled bottle is shown in Figure 13. The proposed position of the glass shoulder (two lines in yellow) can be directly checked against the observed position of the shoulder before opening.

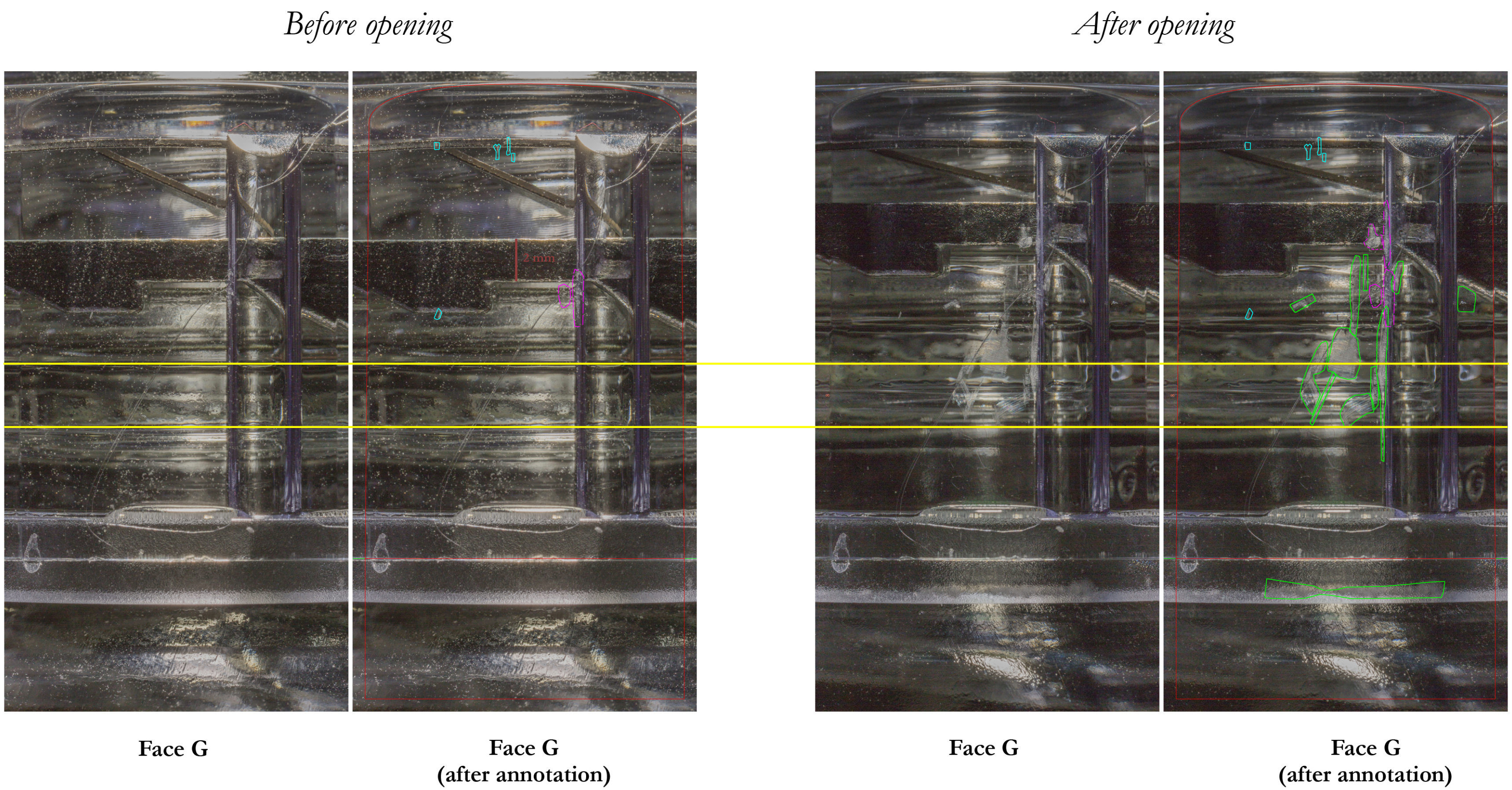

Figure 13: Marks observed following regular closure (left) – U marks are shown in magenta, F marks in light blue – and after re-opening using our tools (right) – T marks are shown in green. The horizontal yellow lines give the position of the glass shoulder before the re-opening of the bottle (in this case 8 clicks).

Two determinations made using the same procedure on the questioned bottles are shown in Figure 15 and Figure 16. Again, three independent examiners carried out the positioning of the glass shoulder and their minimum and maximum assignments of the estimated number of clicks were recorded.

The relationship between the set position of the shoulder and the number of clicks used to close the bottle has been established empirically based on the bottles that were closed under controlled conditions (Figure 14).

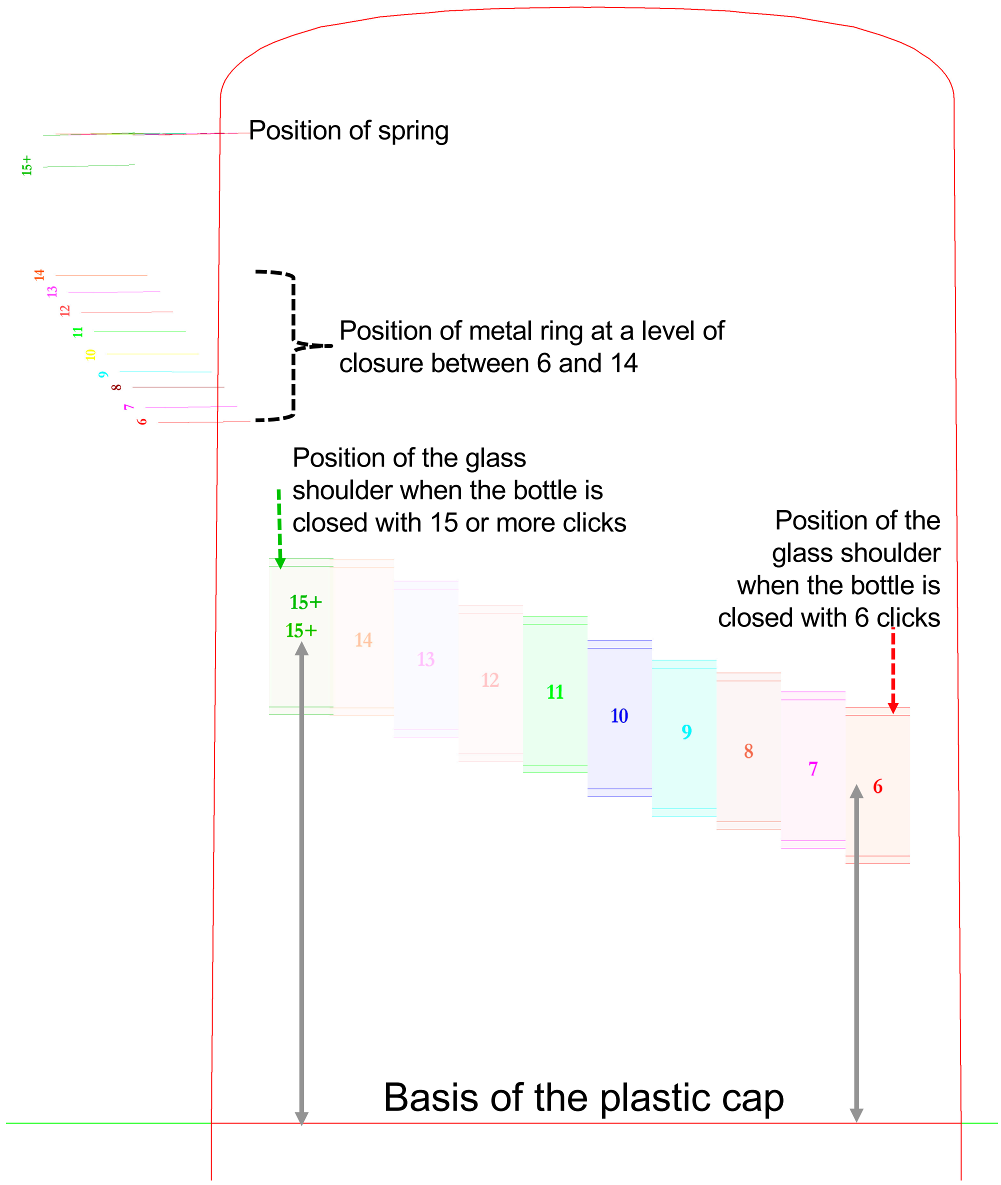

Figure 14: Relation between the height of the glass shoulder relative to the basis of the plastic cap and the number of clicks engaged to close the bottle. "15+" means that the bottle is closed between 15 and 16 clicks. Note that the height of the glass shoulder does not change significantly from 14 clicks to 15+.

The ability of the examiners to determine the state of closure has been checked using 5 bottles that were closed at known levels of closure. Indeed, among the 21 bottles opened by us only 5 of them allowed an assessment of the level of closure according to the proposed method. This is due to the fact that the oblique marks were not always manifest. The range obtained by collating the assessment of three examiners always covered the true value as shown in Table 2.

Bottle number	Estimated minimum and maximum level of closure (number of clicks)	True value
A2029964	6-9	9
A2960232	6-9	8
A3060823	7-9	8
A2960346	6-9	9
A2959991	8-10	8

Table 2: Estimated minimum and maximum number of clicks estimated on the 5 bottles of known status, allowing an assessment of their initial state of closure. The bottle numbers are corresponding to the number of the bottle from the Sochi compatible kit made available to us to develop the methodology.

Likewise, among the 25 bottles showing multiple so-called *T* marks, not all were presenting these oblique marks on multiple faces. Only 15 bottles allowed an assessment of the position of the glass shoulder using these marks. For the 10 remaining bottles, these oblique marks may be absent for multiple reasons such as a variation in the way work with the tools or the skill of the operator.

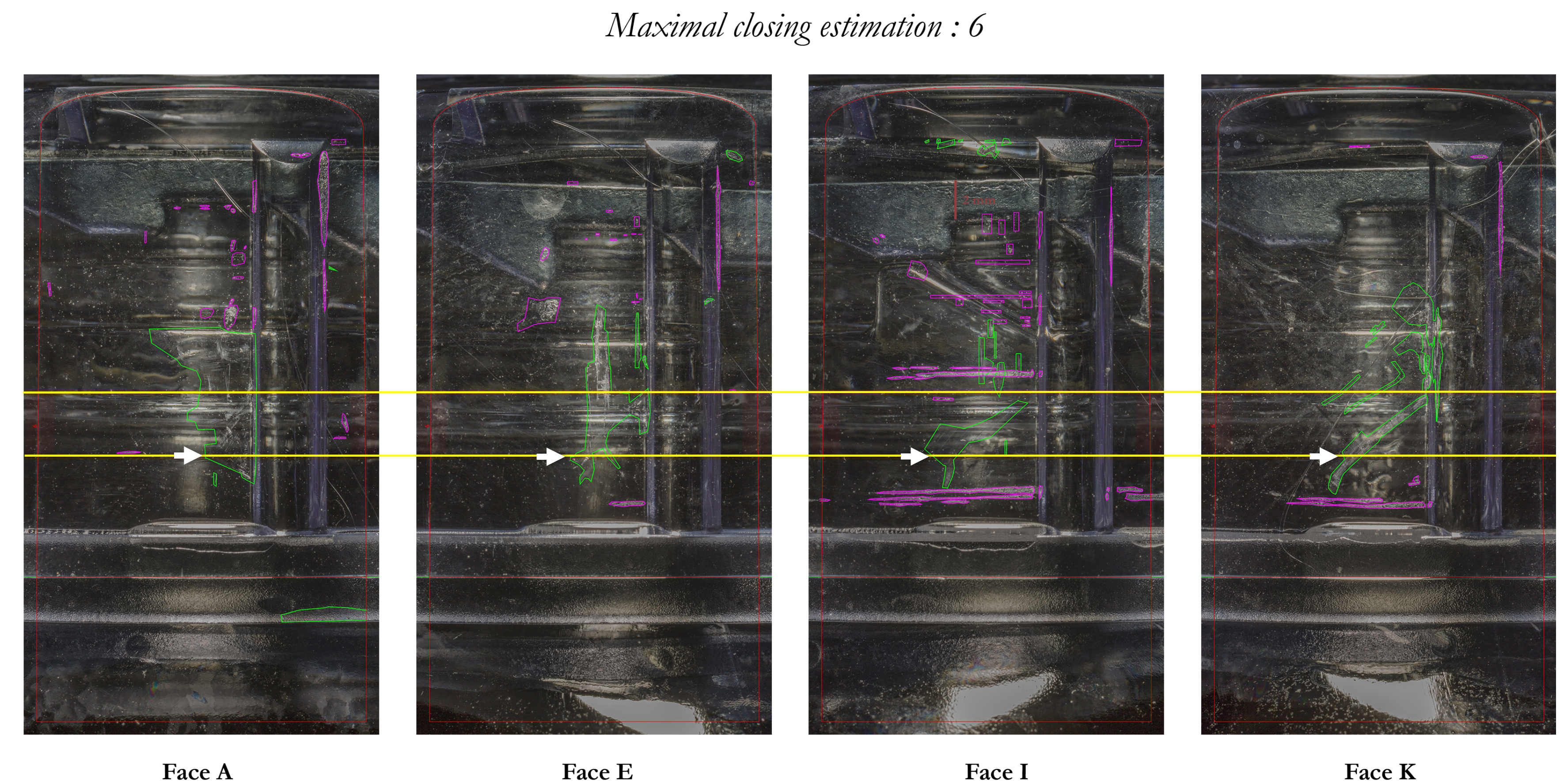

Figure 15: Marks observed on faces A, E, I, and K of one bottle showing multiple T marks. T marks are outlined in green, F marks in light blue and U marks in magenta. The red frame outlines the sides of the face. The two yellow lines across the aligned faces show the set position of the glass shoulder in the maximum state of closure (max 6 clicks). The arrows point to the four oblique T marks that are guiding the positioning of the glass shoulder before re-opening.

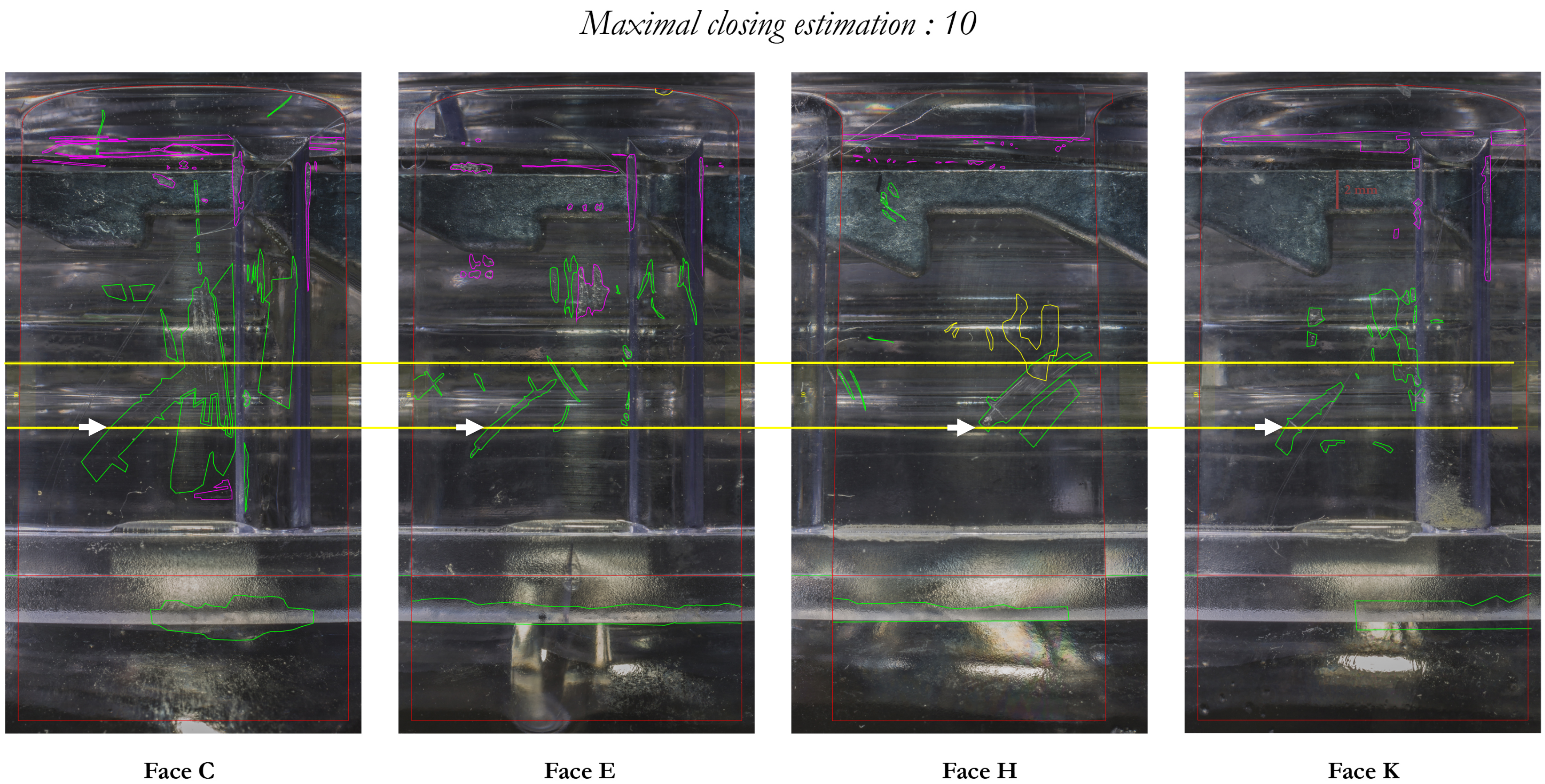

Figure 16: Marks observed on faces C, E, H, and K of one bottle showing multiple T marks. T marks are outlined in green, F marks in light blue and U marks in magenta. The red frame outlines the sides of the face. . The two yellow lines across the aligned faces are the inferred position of the glass shoulder before the bottle had potentially been opened (max 10 clicks). The arrows point to the four oblique T marks that are guiding the positioning of the glass shoulder before re-opening.

The procedure was hence carried out on all the 15 bottles amenable to the procedure. **The results are that all 15 bottles have shown a state of closure below or equal to 12 clicks.** The details for each bottle are given in Table 3.

Bottle number	Estimated minimum and maximum level of closure (number of clicks)
B[redacted]	6-9
B[redacted]	7-10
B[redacted]	6-6
B[redacted]	6-8
B[redacted]	6-9
B[redacted]	6-9
B[redacted]	6-9
B[redacted]	6-9
B[redacted]	6-8
B[redacted]	9-12
B[redacted]	6-12
B[redacted]	6-12
B[redacted]	9-10
B[redacted]	6-10
B[redacted]	6-10

Table 3: Estimated minimum and maximum number of clicks measured on the 15 bottles allowing an assessment of their initial state of closure.

These results mean that, for these bottles, and if we assume that they have been re-opened as alleged, their initial state of closure was of 12 clicks or below. The majority of bottles are closed under 10 clicks. Such a limited level of closure ensured that more space is available between the plastic cap and the glass container, at the time of the potential re-opening.

These observations can be compared with the state of closure measured on the 24 single/double blind bottles. The state of closure is here obtained from the measure of the state of rotation of the cap (30 degrees being one click). **For these 24 bottles, we never made any observation below 13 clicks as shown in** Table 4**.** These bottles have been selected by the IOC and are assumed being closed regularly.

Number of clicks	Number of bottles among the single/double blind samples
6	0
7	0
8	0
9	0
10	0
11	0
12	0
13	2
14	12
15	10
15+	0

Table 4: State of closure (in number of clicks) for the 24 single/double blind bottles. "15+" means that the bottle is closed between 15 and 16 clicks.

Such a high level of closure is also observed on the 127 questioned samples (see Table 5), where all the bottles were closed with at least 12 clicks. Note that here, for questioned bottled, the level of closure is the one observed at reception of the bottle. It can be the original level if the bottle had not been re-opened or the subsequent level resulting from the second closure after the re-opening.

Number of clicks	Bottles concluded "multiple *T* marks"	Bottles concluded "isolated *T* mark(s)"	Bottles concluded "no *T* mark(s)"	Total
6	0	0	0	0
7	0	0	0	0
8	0	0	0	0
9	0	0	0	0
10	0	0	0	0
11	0	0	0	0
12	0	0	2	2
13	0	1	3	4
14	12	9	40	61
15	11	8	32	51
15+	2	0	7	9
Total	25	18	84	127

Table 5: State of closure (in number of clicks) for the 127 questioned bottles. "15+" means that the bottle is closed between 15 and 16 clicks.

This last analysis of the marks observed across the 25 bottles for which a conclusion of "multiple so-called *T* marks" had been reached has shown that, if we assume that these bottles had been tampered with using metallic tools as alleged, their initial state of closure, at least for the 15 bottles that were amenable to the analysis, was always below 12 clicks. That is a lower level of closure compared to the level (at least 13 clicks) observed on the 24 single/double blind samples (bottles chosen by the IOC from the Sochi games). Among the 127 questioned bottles, none of them were closed with less than 12 clicks.

Summary of the main results

We reported in the above sections on the following developments:

- Based on the description of the alleged opening method provided by Dr Rodchenkov, specific tools have been designed. When used in tandem on both sides of the plastic cap, they allow the re-opening of closed bottles from BEREG-KIT®.
- The method has been applied on a series of Sochi compatible bottles (new out of their box, regularly closed and re-opened with the designed tools). All marks left on the inside of the plastic cap have been duly recorded and characterised. A dinstinction can be made between the *F* and *U* marks that are either due to the manufacturing or to the regular usage of the bottles whereas *T* marks are consecutive to the forced re-opening of the bottles with the tools.
- A systematic examination methodology for the bottles has been designed. It includes (i) a standardised photographic setup allowing the non-destructive 360 degrees photographic recording of all the 12 faces of the plastic cap and the visualisation of marks; (ii) when relevant and feasible, marks of interest were also recorded at higher magnification; (iii) marks were annotated distinguishing *F*, *U* and *T* marks; (iv) a set of possible conclusions that could be reached have been specified alongside with an expression of the level of support that the observations will bring in favour of the allegation of the tampering process or in favour of the normal closure of the bottle.
- The method has been applied to three batches containing in total 127 questioned bottles, 12 positive/negative controls and 24 single/double blind samples coming from the Sochi games but associated with other countries. All conclusions reached have been subjected to a blind peer-review process by a second team of examiners.

- Specific marks (typically the oblique marks) found on the inside of the plastic cap of the bottles allow to robustly predict the degree of initial closure of the bottles that had been forcibly opened as alleged and using tools similar to the tool that we designed.

The results obtained after the examination of 127 questioned bottles from the Sochi games, delivered between the 1st and the 24th of February 2014 to the Sochi laboratory are the following:

(i) Among the 127 questioned bottles, 20% of these questioned bottles presented multiple *T* marks (25 bottles), 14% showed isolated *T* marks (18 bottles), the remaining 66% showed no *T* marks (84 bottles);

(ii) All bottles examined (including the single/double blind samples) were closed between 12 clicks and 15+ (the maximum possible closure) and;

(iii) Under the assumption that bottles concluded with "multiple *T* marks" have been tampered with using metallic tools as alleged, for 15 bottles that were amenable to a measure, their estimated initial degree of closure is always of 12 clicks or below, meaning that they were not fully closed.

Lausanne, 30th of November 2017.

Prof. Christophe Champod

Appendix: Statement of qualification

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The undersigned, Prof. Christophe Champod, is full professor of forensic science at the School of Criminal Justice (in French *Ecole des Sciences Criminelles* - ESC) of the Faculty of Law, Criminal Justice and Public Administration (FDCA) of the University of Lausanne (UNIL). He received his M.Sc. and Ph.D. (summa cum laude) both in Forensic Science, from the University of Lausanne, in 1990 and 1995 respectively. Remained in academia until holding the position of assistant professor in forensic science. From 1999 to 2003, he led the Interpretation Research Group of the Forensic Science Service (UK), before taking a full professorship position at the School of Criminal Justice (ESC) of the University of Lausanne. He is in charge of education and research on identification methods and maintains an activity as an expert witness in these areas. He is also operational manager of the ISO/SEC 17025 accredited forensic laboratory of the ESC. In 2015, he received the *Distinguished ENFSI (European Network of Forensic science) Scientist Award* for his contribution to forensic science.

The first forensic examination team is composed of 10 members of staff, whereas the team of peer-reviewers counts 4 members. All staff members are forensic scientists affiliated either to the ESC or to the LAD.