The price of a CEDIA determination of vitamin B₁₂ and folate is $8.50 per sample, whereas the radioassay costs $3.50. Advantages of the CEDIA over the radioassay are that laboratory personnel are not exposed to ionizing radiation from the radionuclides used, duplicates of samples can be run simultaneously, the analysis is much faster (twofold), and the technique is applicable for routine use in laboratories without a radioactivity license.

References

CLIN. CHEM. 38/5, 768–775 (1992)

Design and Evaluation of an Anti-Evaporative Cover for Use with Liquid Containers

C. A. Burtis¹,² and J. S. Watson¹

We have designed an anti-evaporative cover for use with the sample and reagent cups and other liquid containers that are required in automated analytical systems. This cover, which is simple in design, consists of a baseplate and a cylindrical chimney. By increasing the height and decreasing the inner diameter of the chimney, evaporative losses can be reduced to <0.1%/h; thus, aliquots of sample and reagents can be allowed to remain in their cups and containers for several hours before an analytical error due to evaporation will be measurable. We have also modified a model that we previously developed and validated to estimate evaporative losses from open sample cups, to allow us to predict evaporative losses from cups and containers fitted with the new type of cover. This model confirms that the magnitude of the evaporative loss is inversely proportional to the resistance provided by the headspace above the sample in the cup and by the space defined by the chimney of the cover. With chimney heights ranging from 12 to 36 mm and their inner diameters from 1 to 4 mm, >70% of the resistance to evaporation is provided by the cover.

Additional Keyphrases: sample handling - variation, source of

Previous studies have demonstrated that the evaporative loss of volatile components from a sample in a sample cup can have a significant effect on analytical accuracy, because the concentrations of nonvolatile analytes increase (1-5) and the concentrations of the volatile analytes decrease (7, 8) in the sample. Depending on environmental conditions such as temperature, humidity, ambient air flow, and the geometry of the cup, analytical errors of 1-10% have been reported (5).

Analytical error has always been a concern to laboratorians and manufacturers of diagnostic equipment (9-11); however, it is now of particular importance, given the implementation of new laboratory regulations (12) in the Clinical Laboratory Improvement Act (CLIA) of 1988. As mandated by these regulations, each clinical laboratory must demonstrate acceptable performance; failure to do so can result in loss of accreditation and revocation of its legal license to operate. Consequently, the new regulations will require laboratorians and manufacturers of diagnostic equipment to reassign their analytical goals (13, 14) and take proactive steps to reduce all sources of analytical error.

Evaporative loss is one source of analytical error that must be minimized in light of the new CLIA-88 regulations. For example, to achieve a passing grade for a proficiency testing (PT) challenge for serum sodium, a laboratory must report a measured value that falls within a range defined by the target value ±4 mmol/L (12). Thus, if a PT sample has a sodium concentration of 140 mmol/L, an evaporative loss of only 3% will lead to overestimation of the sodium concentration and failure of the PT challenge.

Various measures have been used to minimize the effect of sample evaporation on analytical error. These include minimizing the residence time of the sample in its cup (15, 16); selecting a sample cup with optimal geometry (5); maintaining an optimal liquid level within the cup (4, 5); and protecting the surface of the sample. Techniques used in this latter category include layering the sample surface with silicone oil (17, 18), protecting the sample surfaces by placing a cover over the entire sample carousel or tray (3, 19), or capping the

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individual sample cups (15, 20–23). Such techniques are only partially effective in reducing the magnitude of evaporative losses from sample cups; several recent studies (15, 16, 19, 22–25) have documented evidence that evaporative loss continues to be a problem in several modern analytical systems. Because of our continuing interest in the problem of evaporative loss, we have designed and evaluated a new type of cup cover that reduces evaporative loss to <0.1%/h. Here we describe the design of this new cover, present data demonstrating its effectiveness in reducing evaporative loss, and discuss a modified evaporative model that provides a theoretical basis for explaining the effectiveness of the new cover.

Materials and Methods

Cover Design

Figure 1 shows a cross-sectional view of the new sample cup cover and a typical sample cup. Features of the new cover include a baseplate that fits over the top of a sample cup and a cylindrical chimney that is open to the atmosphere, thus allowing access of a sampling probe to the liquid contents of the cup. Critical dimensions of the cover and cup are \( d_c \) the internal diameter of the chimney; \( Z_c \) the vertical height of the chimney; \( d_1 \), the internal diameter of the sample cup; and \( Z_1 \), the vertical distance from the top of the cup to the surface of the sample liquid. After a given time \( t \), this latter height becomes \( Z_{1c} \) as the liquid level falls because of evaporation. To measure the effect that the critical dimensions of the cover would have on decreasing the magnitude of evaporative loss, we fabricated several covers from solid plastic pipe; diameters varied from 1 to 10 mm and heights from 2 to 36 mm. These covers have a base diameter that would allow them to fit tightly over the tops of 500- to 2000-μL sample cups (DuPont Instruments, Wilmington, DE 19803). When filled with various volumes of liquids, these cups have the critical dimensions listed in Table 1.

![Diagram](image)

**Fig. 1.** Cross-sectional view of the anti-evaporative cover and a typical sample cup from which evaporation has occurred during the time \( t \).

\( d_c \) = internal diameter of cover chimney; \( Z_c \) = height of chimney; \( d_1 \) = internal diameter of sample cup; \( Z_1 \) = vertical distance from top of sample cup to the level of liquid; \( Z_{1c} \) = vertical distance from top of sample cup after the liquid level has dropped because of evaporative loss after time \( t \).

<table>
<thead>
<tr>
<th>Table 1. Physical Dimensions of the Sample Cups When They Contain Different Sample Volumes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume, μL</td>
</tr>
<tr>
<td>---------</td>
</tr>
<tr>
<td>500</td>
</tr>
<tr>
<td>250</td>
</tr>
<tr>
<td>375</td>
</tr>
<tr>
<td>450</td>
</tr>
<tr>
<td>500</td>
</tr>
<tr>
<td>2000</td>
</tr>
<tr>
<td>1000</td>
</tr>
<tr>
<td>1500</td>
</tr>
<tr>
<td>1800</td>
</tr>
<tr>
<td>2000</td>
</tr>
</tbody>
</table>

Quantitative Measurement of Evaporative Loss

To quantitatively determine the effectiveness of the anti-evaporative covers, we measured evaporative losses both gravimetrically and chemically. In the gravimetric studies, specific volumes of water were dispensed into 500- and 2000-μL sample cups. Covers of various dimensions were placed on the cups, and the weight loss of each was determined as a function of time by weighing them at timed intervals up to 48 h. For comparison, evaporative losses were also measured from uncovered cups and from cups that had been capped with a snap-on cap having a height of 0 mm and central aperture of 3 mm (15). To ensure a tight seal, a strip of adhesive tape was placed around the seal between each cup and cover. The analytical balance used (Model AE163; Mettler Instrument Corp., Hightown, NJ 08520) had a repeatability of ±0.01 mg and had been calibrated against weights certified by the National Institute of Standards and Technology (Gaithersburg, MD 20899). At the time of each experiment, the ambient temperature and relative humidity were determined and recorded. Relative humidity was measured with a Bendix Psychrometer (Model 566-2; Fries Instrument Division, Baltimore, MD 21227). At the completion of the individual experiments, the results from each were processed and the relative evaporative losses (%/h) determined. For comparative purposes, the evaporative losses for all the various sample–cup combinations were ratioed against those from the uncovered cups.

In the chemical studies, we used a Dimension analyzer (Model 380; DuPont) to examine various pooled sera for several components under various sets of experimental conditions. In these studies, measured volumes of the pooled sera were dispensed into sample cups and covered with the various anti-evaporative covers. These cups were then placed in a Dimension sample carousel and allowed to stand at ambient conditions for 48 h. At the end of this period, we removed the anti-evaporative covers from the cups and replaced them with the caps that are routinely used in operating the Dimension. The carousel with the recapped cups was then placed in the analyzer, and the requested analyses were performed.

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For baseline measurements, fresh samples of the pooled sera were analyzed at time zero and at 48 h. As with the gravimetric studies, both cups that were uncapped and those with the fitted DuPont caps were processed and analyzed under the same conditions as the cups having the anti-evaporative covers.

Modeling Evaporative Losses from Covered Sample Cups

In a previous study (5), we described a mathematical model that was useful in estimating evaporative losses from uncovered sample cups under known environmental conditions. The theoretical basis for this model was diffusion of vapor through stagnant gas located above a liquid (26). Gravimetric and chemical studies conducted in our laboratory (5) and by Spandrio (4) have confirmed the validity of this model. However, recent data (15) indicate that the model was unsatisfactory for estimating evaporative losses from capped or covered sample cups. Consequently, we have modified and extended the original model to describe the evaporative behavior of covered cups.

In the original model, we noted that the diffusion of vapor through a stagnant air mass can also be described as resistance to mass transfer as the vapor diffuses into the headspace located above a liquid surface. Such resistance (R) is analogous to electrical resistance and can be described by the following relationship:

\[ R = C \cdot \frac{Z}{A} \]  

where Z = height of stagnant air mass (i.e., the vertical distance from the surface of the air-liquid interface to the top of the sample cup), cm; A = area of sample cup at the liquid-air interface, cm²; and

\[ C = \rho \cdot \frac{R \cdot T}{[P \cdot M \cdot D \cdot \ln(P_2/P_1)]} \]  

where \( \rho \) = density of water, g/cm³; \( R \) = gas constant = 82.05 atm · cm³/(mol · K); \( T \) = temperature, K; \( P \) = atmospheric pressure, atm (1 atm = 101 kPa); \( M \) = molecular mass, g/mol; \( D \) = diffusivity of water in air, cm²/s; \( P_1 = P - P_{H_2O} \) (\( P_{H_2O} \) = vapor pressure of water), atm; and \( P_2 = P - P_{H_2O} \cdot RH \) (RH = relative humidity, %), atm.

Thus, as described by Ohm's law, the conductance and mass transfer of vapor (\( \frac{dv}{dt} \)) would be proportional to the reciprocal of resistance:

\[ \frac{dv}{dt} = \frac{1}{R} = \frac{A}{C \cdot Z} \]  

where \( \frac{dv}{dt} \) = rate of evaporation at the liquid-air interface, cm³/s.

This relationship is identical to equation 3 of our previous model (5). To extend the applicability of the model to covered cups, we have relied on another physical principle, which states that the total diffusion resistance (like a total electrical resistance) is equal to the sum of the individual resistances connected in series (27). In the cup-cover situation illustrated in Figure 1, the total resistance to mass transfer is composed of two components: the volume of air located over the sample in the cup and the airspaces defined by the internal dimensions of the chimney of the cover. Thus, the total resistance (\( R_T \)) to mass transfer (i.e., evaporative loss) can be described as

\[ R_T = R_{\text{sample}} + R_{\text{cover}} \]  

\[ R_1, \text{ the resistance of the chimney, is easily calculated because its inner volume is a cylindrical tube. Therefore,} \]

\[ R_2 = 4 \cdot C \cdot Z_c / [\pi \cdot (d_c^2)] \]  

where \( Z_c \) = vertical height of chimney, cm; and \( d_c \) = inner diameter of chimney, cm.

However, the cup resistance, \( R_1 \), is more difficult to calculate because the vapor rising from the surface of the liquid sample must pass through the headspace in the cup and out the aperture of the anti-evaporative cover on its way to the atmosphere. Fitting the experimental data (as presented later in Results) to various types of cylindrical and conical geometries demonstrated that the cup resistance could best approximate by assuming a conical geometry for the path of the vapor as it diffuses out through the headspace of the cup. Therefore,

\[ R_1 = 4 \cdot C \cdot Z_1 / [(\pi \cdot (d_c \cdot d_1))] \]  

where \( Z_1 \) = vertical distance from liquid surface to the top of cup, cm; and \( d_1 \) = inner diameter of cup, cm.

Evaporative loss would then be proportional to the reciprocal of the total resistance:

\[ \frac{dv}{dt} = \frac{1}{R_T} = \frac{1}{R_1 + R_2} \]  

Substituting from equations 5 and 6 into equation 7, the evaporative loss becomes

\[ \frac{dv}{dt} = \pi [(d_c^2 + (d_c \cdot d_1)]/[4 \cdot C \cdot (Z_c + Z_1)] \]  

We then used this model to describe and confirm the effectiveness of the new anti-evaporative covers in minimizing the evaporative losses from sample cups under various environmental conditions.

Results

Effectiveness of Anti-Evaporative Covers

Results obtained from the gravimetric studies demonstrated that the anti-evaporative covers were effective in reducing evaporative losses from the 500- and 2000-μL sample cups filled with various volumes of water. As summarized in Tables 2 and 3, the magnitude of the evaporative loss from individual cups was a function of
time, cup geometry, sample volume, and the physical dimensions of height and inner diameter of the chimneys of the anti-evaporative covers. As expected, the greatest evaporative loss occurred from uncovered cups and ranged from 1.5% to 2.5% per hour (Table 2). Confirming an observation made in a previous study (7), the use of plastic caps with apertures of 3 mm reduced evaporative losses to 0.5–1.5%/h and were more effective when used with the larger (2000-µL) cups than with the smaller (500-µL) ones.

As predicted by equation 1 and confirmed by the gravimetric data, the effectiveness of the new anti-evaporative cover in reducing evaporative loss is inversely proportional to the height of its chimney and proportional to the inner diameter of the chimney. As Tables 2 and 3 show, the evaporative losses from the various sample–cup combinations systematically decreased as the chimney heights were increased and their inner diameters decreased. For example, as shown in Figure 2 for the 1000/2000-µL sample volume/cup volume combination, the evaporative loss decreased from 1.7%/h for an uncovered cup to 0.2%, 0.1%, 0.05%, and 0.03%/h when the chimney height of the cover was increased to 2, 12, 24, and 36 mm, respectively. As Figure 2 also shows, the evaporative losses were significantly reduced when the inner diameter of a 12-mm-high chimney was reduced from 10 to 1 mm, the measured evaporative loss for a 1-mm aperture being 0.02%/h.

In the analytical experiments, the concentrations of all the analytes measured (i.e., alkaline phosphatase, glucose, potassium, and sodium) were found to increase in activity or concentration when uncovered and covered cups of pooled sera were allowed to stand under ambient conditions for 48 h before analysis. The sodium data from the 2000-µL cup experiments are summarized in Table 4, and the 1000/2000-µL sample/cup volume data sets are depicted in Figure 3. Paralleling the gravimetric data, the greatest errors from evaporation occurred in the uncovered cups and, depending on the volume of sample placed in them, led to a two- to fourfold increase in sodium concentration when the aliquot of pooled serum were allowed to remain in their cups for 48 h. For example, as shown in Figure 3 for the same 1000/2000-µL combination, the sodium concentration from the uncovered cup after 48 h increased from

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**Table 2. Effect of Chimney Height on Controlling Evaporative Loss from Sample Cups**

<table>
<thead>
<tr>
<th>Sample volume, µL</th>
<th>Evaporative loss</th>
<th>Chimney height, mm*</th>
<th><strong>U</strong></th>
<th><strong>C</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>500-µL cup</td>
<td>%/h</td>
<td>Ratio</td>
<td>%/h</td>
<td>Ratio</td>
</tr>
<tr>
<td>126</td>
<td>1.94</td>
<td>1.00</td>
<td>1.59</td>
<td>1.22</td>
</tr>
<tr>
<td>247</td>
<td>1.44</td>
<td>1.00</td>
<td>1.12</td>
<td>1.28</td>
</tr>
<tr>
<td>376</td>
<td>1.51</td>
<td>1.00</td>
<td>0.96</td>
<td>1.57</td>
</tr>
<tr>
<td>447</td>
<td>1.77</td>
<td>1.00</td>
<td>1.12</td>
<td>1.58</td>
</tr>
</tbody>
</table>

**Table 3. Effect of Chimney Diameter on Controlling Evaporative Loss from Sample Cups**

<table>
<thead>
<tr>
<th>Volume, µL</th>
<th>Chimney diameter, mm*</th>
<th>Evaporative loss</th>
<th><strong>U</strong></th>
<th><strong>C</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cup</td>
<td>%/h</td>
<td>Ratio</td>
<td>%/h</td>
<td>Ratio</td>
</tr>
<tr>
<td>500-µL</td>
<td>245</td>
<td>2.17</td>
<td>1.00</td>
<td>1.82</td>
</tr>
<tr>
<td>2000-µL</td>
<td>992</td>
<td>1.74</td>
<td>1.00</td>
<td>0.57</td>
</tr>
</tbody>
</table>

---

* Standard aperture = 3 mm.
* U = uncovered cup; C = capped cup, height = 0 mm, aperture = 3 mm.
* Ratio = evaporative loss of uncovered cup/evaporative loss of cup being evaluated.
* Conditions: average ambient temperature = 21.0°C; average relative humidity = 31%.

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the target value of 144.3 to 294.2 mmol/L. This large increase in sodium concentration was reduced by increasing the chimney height of the anti-evaporative covers. For example, after 48 h, the sodium concentrations for the pooled sera in cups covered with the 24- and 36-mm-high chimneys were 148.3 and 147.7 mmol/L, respectively.

Note that we conducted the analytical experiments for 48 h so that we could obtain measurable changes in sodium concentration. In routine laboratory operation, the time that samples would be expected to remain in their cups would range from 1 to 8 h. By extrapolating the 48-h data to an 8-h interval, the sodium concentrations for the 2-, 12-, 24-, and 36-mm-high chimneys would be 147.3, 145.9, 145.0, and 144.9 mmol/L, respectively. As is evident in Table 4 and Figure 3, decreasing the size of the aperture of the chimney was also effective in reducing the increase in sodium concentration attributable to evaporation.

Verification of the Resistance Model

As described by equation 8, the modified evaporative model predicts that the magnitude of the evaporative loss from a covered sample cup is inversely proportional to the sum of the resistances to the mass transfer of vapor through the columns of stagnant air located above the sample in the cup and cover. To test this assumption, we calculated the total resistance for each of the cup-volume-cover combinations listed in Tables 2-4 and plotted their reciprocals vs the experimentally measured evaporative loss for each combination. As predicted by the model, the resulting plot (Figure 4) demonstrated a linear relationship between the magnitude of evaporative loss and the reciprocal of the total resistance and showed that the magnitude of evaporative loss can be decreased and controlled by increasing the resistance in the cup-cover combination. Figure 5 illustrates how the height and diameter of each chimney determine the magnitude of the total resistance, which increases as these dimensions increase and decrease, respectively. It is also evident that the resistance due to the cup predominates over that due to the chimney.

Discussion

The results summarised in Tables 2-4 and displayed in Figures 2 and 3 demonstrate that the new anti-evaporative cover effectively reduces evaporative losses from sample cups. Such losses can be reduced to negligible amounts by controlling the height and inner diameter of the chimney on the cover. In actual practice, the utility and applicability of the anti-evaporative cover will depend on the physical dimensions of the cup-cover combination relative to the spatial requirements of the sample probe as it is inserted through the cover into the cup contents and subsequently removed. In addition, the physical dimensions of the sampling probe itself must be considered.

The fact that both the height and the inner diameter of the chimney can be adjusted to control evaporative
Table 4. Effect of Anti-Evaporative Covers in Reducing the Increase in Serum Sodium Concentration as a Result of Sample Evaporation

<table>
<thead>
<tr>
<th>Sample vol, µL</th>
<th>Chimney height, mm°</th>
<th>U</th>
<th>C</th>
<th>2</th>
<th>12</th>
<th>24</th>
<th>36</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td></td>
<td>699.7</td>
<td>299.1</td>
<td>196.5</td>
<td>159.4</td>
<td>152.1</td>
<td>150.2</td>
</tr>
<tr>
<td>RE°</td>
<td></td>
<td>362.8</td>
<td>106.7</td>
<td>37.1</td>
<td>10.2</td>
<td>5.1</td>
<td>3.8</td>
</tr>
<tr>
<td>EER°</td>
<td></td>
<td>10.9</td>
<td>3.2</td>
<td>1.1</td>
<td>0.3</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>1000</td>
<td></td>
<td>294.2</td>
<td>209.2</td>
<td>161.9</td>
<td>153.7</td>
<td>148.3</td>
<td>147.7</td>
</tr>
<tr>
<td>RE</td>
<td></td>
<td>103.3</td>
<td>44.6</td>
<td>11.9</td>
<td>6.2</td>
<td>2.5</td>
<td>2.1</td>
</tr>
<tr>
<td>EER</td>
<td></td>
<td>3.1</td>
<td>1.3</td>
<td>0.4</td>
<td>0.2</td>
<td>0.08</td>
<td>0.06</td>
</tr>
<tr>
<td>1500</td>
<td></td>
<td>266.1</td>
<td>195.1</td>
<td>156.4</td>
<td>149.5</td>
<td>146.8</td>
<td>147.2</td>
</tr>
<tr>
<td>RE</td>
<td></td>
<td>83.9</td>
<td>34.8</td>
<td>8.1</td>
<td>3.3</td>
<td>1.5</td>
<td>1.7</td>
</tr>
<tr>
<td>EER</td>
<td></td>
<td>2.5</td>
<td>1.1</td>
<td>0.2</td>
<td>0.1</td>
<td>0.04</td>
<td>0.05</td>
</tr>
<tr>
<td>1800</td>
<td></td>
<td>274.5</td>
<td>192.8</td>
<td>154.6</td>
<td>149.6</td>
<td>147.4</td>
<td>147.5</td>
</tr>
<tr>
<td>RE</td>
<td></td>
<td>89.7</td>
<td>33.2</td>
<td>6.8</td>
<td>3.4</td>
<td>1.8</td>
<td>1.9</td>
</tr>
<tr>
<td>EER</td>
<td></td>
<td>2.7</td>
<td>1.0</td>
<td>0.2</td>
<td>0.1</td>
<td>0.06</td>
<td>0.05</td>
</tr>
</tbody>
</table>

U = uncovered cup; C = capped cup.
°Conditions: cover aperture = 3 mm; ambient temperature = 25.0°C; average relative humidity = 39%; reference value = 144.7 mmol/L.
°°Conditions: chimney height = 12 mm; ambient temperature = 23.4°C; average relative humidity = 30%; reference value = 144.3 mmol/L.

Fig. 4. Evaporation as a function of total resistance (Rt) to mass transfer of vapor for the 1000/2000-µL sample/cup volume combination losses provides flexibility to an engineer when designing an anti-evaporative cover for cups for use with specific analytical samples. For example, if a particular system has limited space over its sampling compartment and a tight movement of the sampling probe into and out of the sample cup, a short chimney having a narrow inner diameter can be used. On the other hand, if space is not limiting, the height of the cover can be increased.

The need for increasing the chimney height to compensate for widening its diameter is of particular importance when a liquid-level sensing device is integrated into a sampling probe. Several analytical systems now use this type of sampling probe; in general, its cross-sectional diameter is greater than that of a conventional probe. Thus, the design of an anti-evaporative cover for liquid-level sensing probes would require a wider diameter and a compensative increase in the chimney height. Where a liquid-level sensor is used and the space requirements of the sampling probe are extremely tight, the option of increasing the chimney height over the cup may be compromised. In such cases, one can still control evaporation loss by increasing the chimney height via insertion of the chimney into the inner space of the cup (Figure 6). In such cases, the sample cup should be only one-half to three-quarters filled (5). Also, systems that use a liquid-sensing probe may have greater problems with sample evaporation than do systems in which the probe samples from the bottom of the cup. Because evaporation occurs at the liquid-air interface, the change in concentration as a result of evaporation is
greater near this interface, creating a concentration gradient vertically across the height of the liquid in the cup. Therefore, systems with probes that sample just beneath the surface of a sample should exhibit a greater analytical effect due to evaporation than those whose probes sample at a greater depth in the sample cup.

As discussed earlier, manufacturers of automated analytical systems and laboratorians who use the systems have been aware of and concerned about the impact of sample evaporation or analytical error. However, with the continuing trend toward systems having microvolume capabilities and sample management schemes requiring batch processing and computer-scheduled analysis, we can anticipate that sample evaporation will continue to be a problem. In addition, the new CLIA-88 regulations (12) will require us to pay attention to all sources of analytical error, including evaporation, and take active steps to reduce them, given the substantial penalties for failure. Sample evaporation can now be practically eliminated as a source of concern by the use of an anti-evaporative cover, which reduces evaporative loss to an amount that is practically of no significance during a routine workday. In fact, by adjusting the physical dimensions of the chimney of the cover, aliquots of sample and reagent can be left in their containers for several hours or even days without a significant evaporative loss. Thus, analysts will be able to intersperse PT samples randomly throughout a typical analytical run, with the result that the probability of time-related analytical errors such as evaporation occurring in the PT sample will be the same as that for the patients' samples. This feature of the new cover is quite important because the CLIA regulations (12) mandate that PT and patients' samples be processed and analyzed in exactly the same manner. Further, the regulations require the analyst to attest to and document that this has occurred.

In summary, we have designed an anti-evaporative cover for use with individual sample and reagent containers and have demonstrated that evaporative loss can be reduced to <0.1%/h with their use. Although very effective in function, the new cover is simple in design and should be easily and inexpensively manufacturable with use of available plastic molding or extrusion techniques. In addition, the design of the new cover provides access to the surface of a liquid because it has an open path to the surface; therefore, a sampling probe can be inserted through and removed from the cover without having to puncture a membrane or a covering lid. Theoretically, the anti-evaporative effectiveness of the new cover is related to the increased resistance its design provides to mass transfer, which reduces the diffusion of vapor through the headspace within the cup and cover. The magnitude of this resistance can be controlled by increasing the height or by decreasing the diameter of the cover chimney. With the use of such covers, samples of specimens or reagents can be left in their cups or containers for long periods (e.g., 13 to 130 h) before evaporation loss will result in an appreciable change in the concentration or activity of an analyte in the liquid.

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