

Investigations into the Efficiency of Anti-Fogging Agents

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Abstract

Preliminary investigations have been carried out on three commercially available anti-fogging agents in order to determine their ability at preventing misting.

When exposed to saturated air, polysiloxane coated polycarbonate substrates that had been treated with the agents remained free from misting as the condensed moisture formed a uniform film of water over the surface of the substrate. An agent's ability to prevent further misting from occurring after the substrate was allowed to dry could be related to the rate at which the agent was lost through drainage of the water film.

Qualitative evaluations have been carried out to assess the performance of the agents under misting conditions and also to determine the effects of short-term "ageing" on surfaces pretreated with the agents. Quantitative measurements were also carried out on two of the three agents using ultra-violet spectroscopy to determine their rates of removal via drainage.

Introduction

In the design stage of a typical respirator, considerable care is taken to prevent misting of the eyepieces from occurring. The usual solution is to direct inspired air from the canister over the internal surfaces of the eyepieces, thus causing rapid evaporation of any condensed moisture formed during exhalation or through climatic changes within the respirator. Misting can be a problem however, when the ambient temperature

is very low or if the respirator does not possess an air-management system. In these situations, an anti-fogging agent may be required to overcome the problem of misting. Initial investigations on three commercially available anti-fogging agents have therefore been carried out in order to establish a method of determining comparative ability at preventing misting.

Misting and Anti-Fogging Agents

Figure 1a illustrates normal light transmission through an optically transparent substrate.

When warm, moist air comes into contact with a cold, optically transparent surface, the air temperature will drop and water vapour condense if the dew point is reached. On an untreated surface, the condensed water forms a sheet of ultra-microscopic droplets which scatter transmitted light and obscure the vision (Figure 1b). Misting or fogging is said to occur.

There are several ways to prevent misting from occurring on transparent surfaces¹ but perhaps the most convenient approach is to apply a temporary hydrophillic ("water-loving") coating, usually referred to as an "anti-fogging agent."

Anti-fogging agents are surfactant in nature and numerous surface active compounds including long chain sulphonic acid salts² and derivatives of polyethoxylated fatty amines³ have been described. They can be applied as very thin films without interfering with transparency and function by lowering the surface tension of any condensed moisture that comes into contact with the treated surface.

If warm, moist air comes into contact with a treated surface, misting is prevented as the resulting condensation forms a continuous, transparent water layer rather than a sheet of ultramicroscopic droplets (Figure 1c). Provided that the water layer remains continuous, light transmission (and therefore vision) remains unaffected.

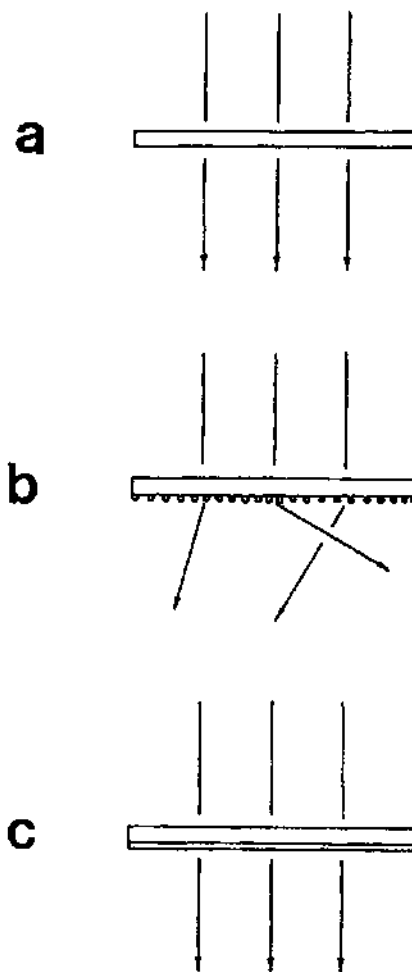


Figure 1. Light transmission through (a) a transparent substrate, (b) a fogged substrate, and (c) a substrate with a continuous water layer.

Experimental

Agent Persistency

Figure 2 is an exploded diagram of the apparatus used to assess the persistency of the agents.

Polycarbonate eyepieces (2 mm thick and dip-coated with a polysiloxane protective layer) from the S10 service respirator were used as convenient test pieces and were positioned approximately 6 cm above the surface of thermostatically heated water maintained at 37°C. Room temperature was 20°C ± 3°C and the air temperatures directly above and below the eyepieces were 30°C ± 2°C and 34°C

respectively. Each eyepiece rested in a circular recess in a removable shelf which was designed to maintain water vapour saturation of the air beneath the eyepieces and prevent air currents that might have otherwise impeded condensation.

Sample Preparation: The eyepieces were washed in an aqueous Teepol solution, rinsed with distilled water and dried in air (37°C, 30% RH) prior to use. Agents 1 and 2 were received as impregnated cloths and applied according to the manufacturers' instructions. Agent 3 was supplied as a liquid and was smeared over the surface of the

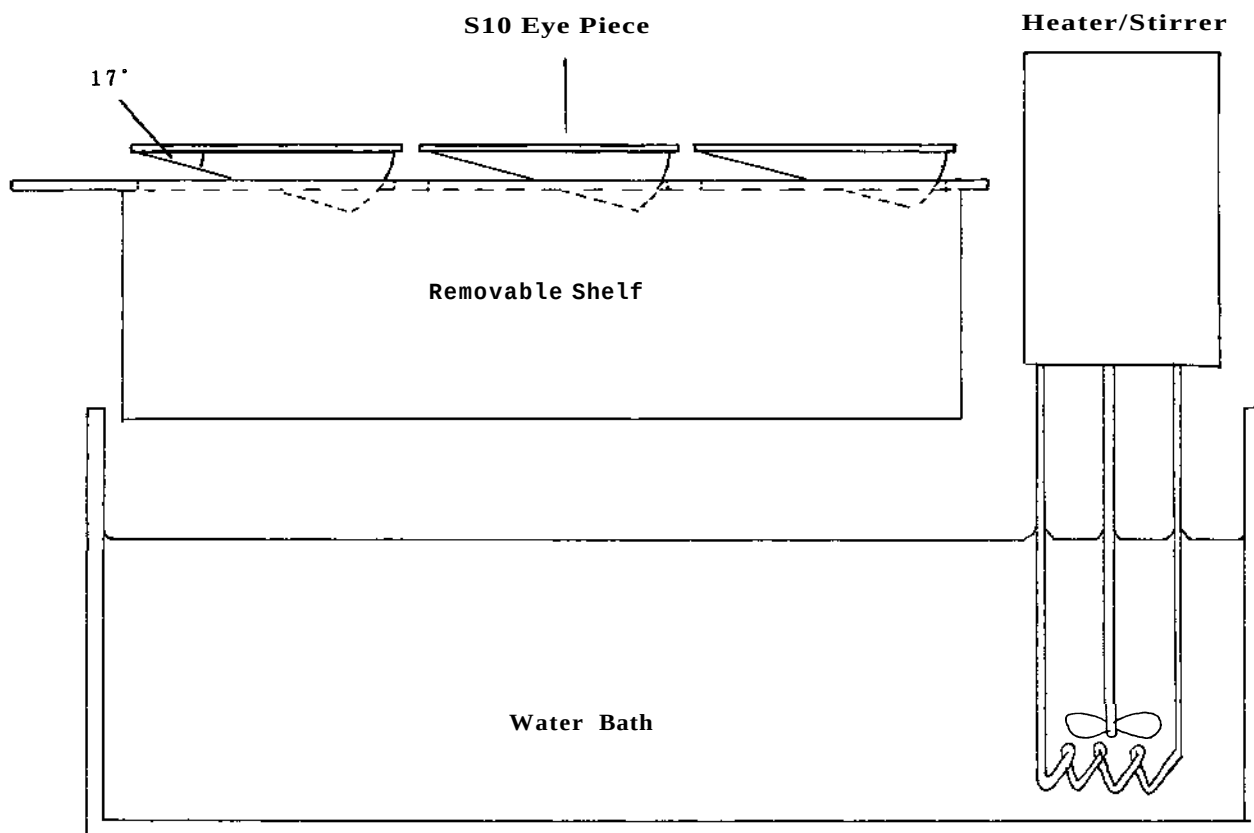


Figure 2. Apparatus.

eyepiece (three drops) and lightly polished with a clean tissue. (Although care was taken to apply the agents uniformly and equally to each of the eyepieces, there were inevitable variations in the quantity of agent applied).

Procedure: Three eyepieces that had each been previously treated with one of the three agents were placed into position above the water bath for 20 minutes. A visual inspection of the condensed water films was made after this time and the eyepieces then removed, stood vertically in a draught-free container and allowed to dry (ca. 10 minutes). The dried eyepieces were then re-exposed to the water bath and the 20 minute fog/10 minute dry cycles repeated until the condensed water films were considered unacceptable.

Short-Term Ageing

The procedure and conditions for assessing the effects of long-term ageing were identical to

those used to assess agent persistency except that the treated eye pieces were placed in a non-dust proof drying cabinet (37°C, 30% RH) for 24 hours prior to use. Eyepieces 1, 2, and 3 were treated with Agents 1, 2, and 3 respectively.

Rates of Loss of Agents 1 and 2

The apparatus illustrated in Figure 2 was used to help measure the rate of loss of the agents. The conditions were identical to those previously described.

By measuring the **absorbances** of dilute solutions containing known amounts of pure agent (approximately 0.3–4.0 mg), it was possible via Beer's law⁴ to describe a simple calibration formula, $Q=Ca$, and use it to determine the quantities of agent that had drained from the eye pieces during misting. Thus, A is the **absorbance** of a solution of the agent, Q is the quantity of agent present in mg and c is the quantity of agent per

unit absorbance. The values of c for Agents 1 and 2 were 2.0 and 3.2 mg/unit absorbance respectively. Samples of pure agent were obtained by extracting the impregnated cloths with ethanol, filtering the solutions and then removing the volatile components under reduced pressure to yield turbid, viscous oils. The system error was ± 0.001 absorbance units corresponding to ± 0.002 mg for Agent 1 and ± 0.003 mg for Agent 2. No account was made for random error.

An eyepiece treated with either Agent 1 or 2 was placed into position above the water bath and the time noted when the first droplet appeared (usually 3-3.5 minutes). When the droplet was large enough, the eyepiece was quickly and carefully removed from the shelf and the droplet collected using a 250 ml syringe. The eyepiece was then replaced and the contents of the syringe injected into a 10 mm path length uv cell. Having filled the cell to a constant volume line with distilled water, the absorbance of the resulting solution was measured at 255 nm using a Philips

PU 8720 uv/visible spectrophotometer. By using the calibration formula, the quantity of agent present in the droplet could thus be determined. The cell was then **rinsed-out**, the next droplet collected and its absorbance measured in the same manner. This procedure was carried out until no more agent could be detected. The eyepiece was then washed, re-prepared and the process repeated until a total of six experiments were performed on each agent.

Note: At the end of each experiment, the eyepieces were allowed to dry and then re-exposed to the water bath. Eyepieces that had been previously treated with Agent 1 **misted-over** immediately and subsequently gave broken and distorted water films after 10 minutes. Eyepieces previously treated with Agent 2 gave patchy misting on re-exposure to the water bath followed by very poor water films after 10 minutes. These observations indicated that all or nearly all of the agent was lost by the end of these experiments.

Results and Discussion

Agent Persistency

The effectiveness of an anti-fogging agent depends upon two important factors: (a) its ability to wet the substrate, and (b) its rate of removal under a given rate of condensation. Assuming that the agent possesses good hydrophillic characteristics, (b) becomes the limiting factor and is governed largely by the solubility of the agent. Thus, the slower the rate of agent removal for a given rate of condensation, the greater the agent's persistency.

The geometry of the S10 eyepiece is clearly shown in Figures 3a (inner surface) and 3b (outer surface).

Within seconds of placing the freshly treated eyepieces into position above the water bath, a distinct rainbow was seen to cover the entire surface of each eyepiece when viewed in the correct light. This rainbow effect (caused by light interference within the very thin film of initially condensed water) gradually faded as the water film thickness increased. After ca. three minutes, agent-loss began to occur as water droplets slowly formed and dripped from the bottom of the eyepieces (angle of slope = 17° , see Figure 2). The

water film on each eyepiece at the end of the first 20 minute fog cycle was uniform and continuous, indicating that all three agents performed well and caused complete wetting of the eye pieces. (*nb* No gravity drainage of the water films was observed during the drying cycles, thus indicating that agent-loss only occurred throughout exposure to the water bath).

Similar observations were made during a second 20 minute fog cycle, indicating that the amount of agent remaining on each eye piece at the beginning of this fog cycle was sufficient to cause complete wetting of the condensed moisture.

At the end of a third 20 minute fog cycle and after initial misting, the water films on eyepieces treated with Agents 1 and 3 were broken and discontinuous, indicating a severe or total loss of agent from these eyepieces during the previous fog cycle. (Note, that despite there being little or no agent present during the latter part of the previous fog cycle, the water films on these eyepieces remained intact since water vapour was condensing onto an established water film). The water film on the eyepiece treated with Agent 2 was still uniform and continuous.

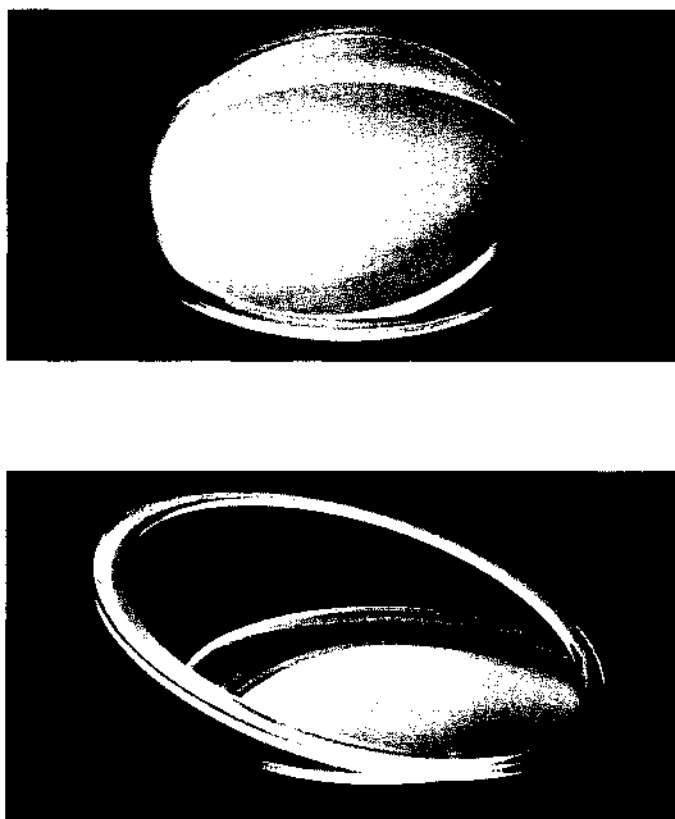


Figure 3. The S10 Eyepiece: Inner surface (a) and outer surface (b).

After being allowed to dry, the eyepiece treated with Agent 2 was exposed to the water bath for a fourth 20 minute fog cycle. After initial misting, the water film became broken and discontinuous indicating that Agent 2 was lost during the third fog cycle and is therefore a slightly more effective anti-fogging agent than the other two under these conditions. (*nb* It is important to note that the results reported here are *typical* of those found over a large number of repeat experiments).

The water films on "aged" eyepieces treated with Agents 1, 2 and 3 were of a poorer quality compared to those in the previous experiment. Pinholing in the water film (caused by the nonwetting of surface debris) was visible at the end of the first 20 minute fog cycle and caused coalescence and break-down of the films to occur in small areas. The water film on the eyepiece treated with Agent 2 was very poor and non-uniform after a third 20 minute fog cycle.

Effects of Short-Term "Ageing"

Since it may sometimes be more convenient to apply an anti-fogging agent several hours or even days before use, it is important to determine whether its effectiveness alters after application.

Assuming that the chemical nature of the agent does not change, its volatility is low and no other physical change occurs, the major problem associated with a pre-treated substrate would be exposure to air-borne contamination.

Rates of Loss of Agents 1 and 2

The rates of loss of Agents 1 and 2 were determined by measuring the quantity of agent present in the droplets that continuously formed and dripped from the bottom of the eyepieces under the misting conditions described. This was carried out by measuring the uv absorbance of *equivolume*, aqueous solutions that contained the droplets collected over a period of time (approximately 40–70 minutes). Measurements on Agent 3 were precluded because of its inactivity in the uv region.

It has not been assumed that the uv-active and antifogging components were one and the same, but the rate of loss of the uv-active component was taken to mirror that of the applied composite layer.

Figure 4 shows the cumulative loss of Agent 1 versus time for six repeat experiments. The six curves flatten-out to values assumed to correspond to the initial amounts of Agent 1 that were present on the eyepiece at the beginning of each experiment.

The amounts applied can be seen to vary between 0.25 and 0.46 mg with a mean value of 0.34 mg. The time taken for the first droplet to appear (and thus the time at which agent-loss started to occur) was three minutes in each case.

The results have also been plotted to show how the amount of Agent 1 remaining on the eyepiece varies with time and exponential regression analysis of these new curves showed that the rate of loss of Agent 1 appeared to follow first order Arrhenius kinetics.⁵ The empirical rate constants obtained for each of the six curves were in good agreement with each other despite the fact that the curves did not appear to belong to the same "family." This would indicate that the drainage process is a complex one and direct analogy with Arrhenius-style kinetics should be avoided.

Each curve approximated to the function $Q = A \exp(-kt)$, where Q is the quantity of agent remaining after time t , A is a constant, and k is the rate constant. The rate constants found for Agent 1 are listed in Table 1. It should be noted that the intercepts on the vertical axis would not correspond to the initial quantities of agent present on the eyepieces since agent loss does not occur until around three minutes.

Figure 5 shows the corresponding sets of curves for the cumulative loss Agent 2. Again, agent loss began to occur at around three minutes.

The initial amounts applied to the eye piece varied between 0.23 and 0.34 mg with a mean value of 0.27 mg. The average amount applied was thus slightly less than that for Agent 1.

Similar exponential regression analysis indicated that the rate of loss of Agent 2 also appeared to follow first order Arrhenius kinetics.⁵ Table 1 lists the rate constants found for Agent 2.

It can be seen from the mean rate constants of the two agents that under identical conditions of misting, Agent 2 was slightly more persistent than Agent 1. These results were in good agreement with the observations from the agent persistency experiments.

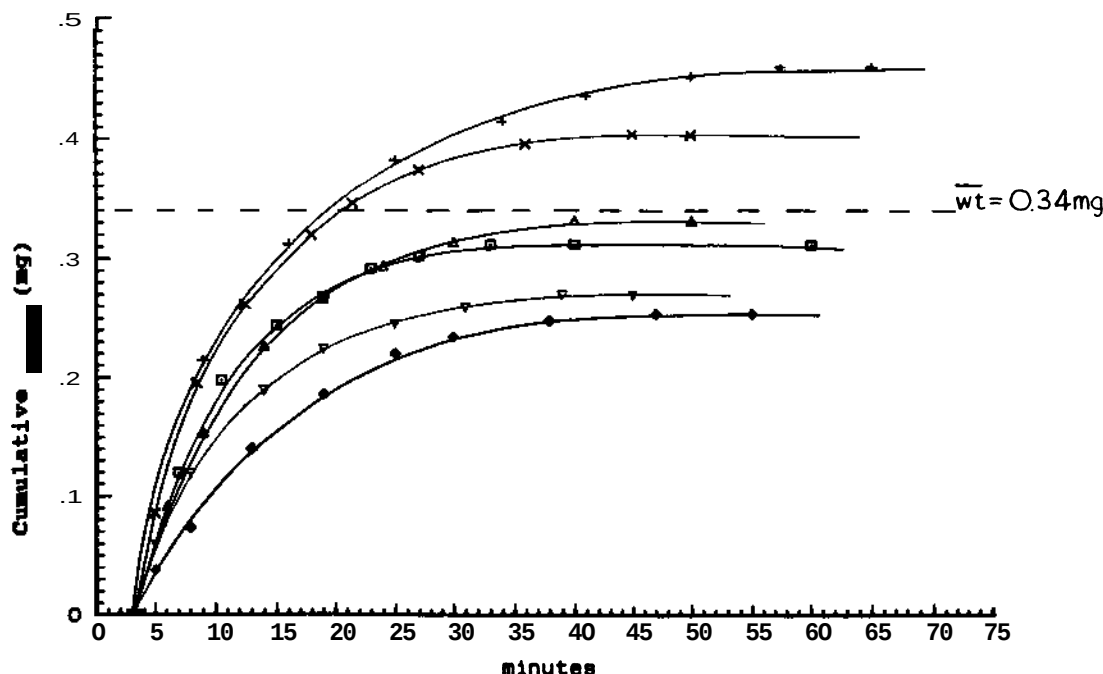


Figure 4. Cumulative loss of Agent 1 from eyepiece vs time.

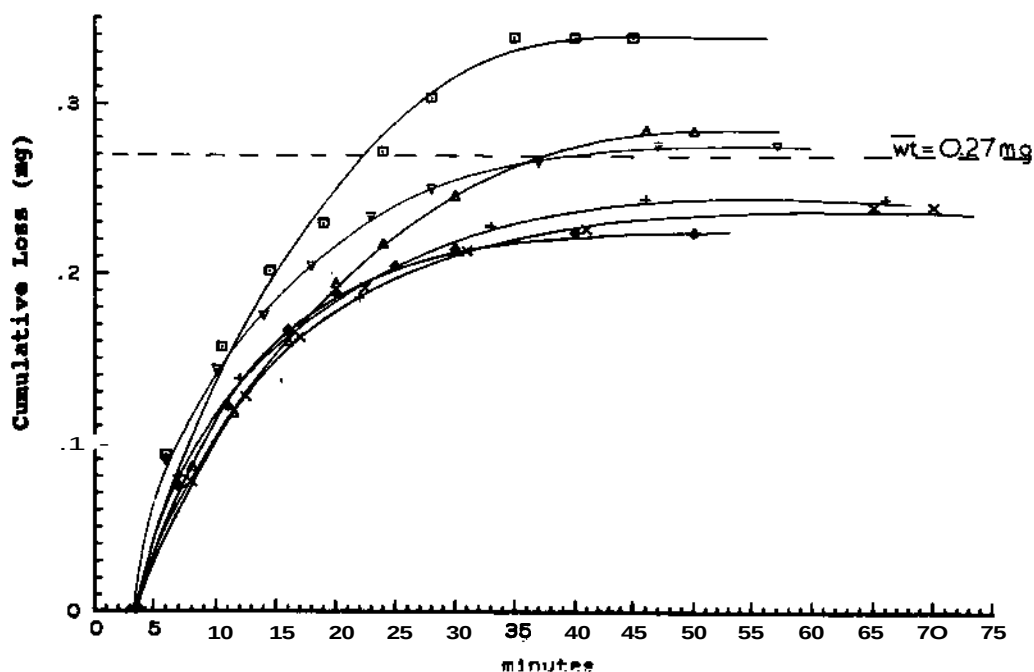


Figure 5. Cumulative loss of Agent 2 from eyepiece vs time.

Table 1. Rate constants for Agent loss (min^{-1}).

Experiment	Agent 1	Agent 2
□	0.14	0.08
△	0.11	0.07
▽	0.11	0.10
◇	0.10	0.12
+	0.08	0.09
×	0.11	0.08
Mean Value	0.11	0.09

Conclusion

1. Agent 2 has been shown to be a more effective anti-fogging agent than Agents 1 or 3, both qualitatively and quantitatively.
2. The experiments have shown that a simple and effective way of measuring comparative anti-fogging ability exists, provided that the agents are uv active.
3. The misting conditions used in the experiments were far more severe than those

likely to be found within a respirator under normal use. This is especially important to note when considering the effects of short-term "ageing" on anti-fogging agents. Surface debris which can seriously disrupt a condensed water film is unlikely to affect a thin, transient film formed by warm breath, and all three agents would therefore be expected to have better performances "in the field."

References

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