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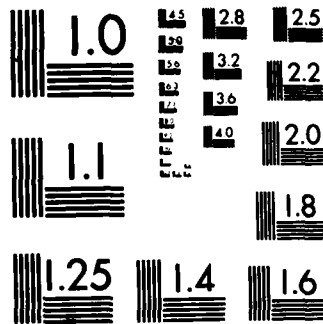
SUBCONTACT LENS BUBBLE FORMATION UNDER LOW ATMOSPHERIC  
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# SUBCONTACT LENS BUBBLE FORMATION UNDER LOW ATMOSPHERIC PRESSURE CONDITIONS

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Progress Report for Period June 1984 - December 1985

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NOTICES

This progress report was submitted by personnel of the Ophthalmology Branch, Clinical Sciences Division, USAF School of Aerospace Medicine, Aerospace Medical Division, AFSC, Brooks Air Force Base, Texas, under job order 2729-06-03.

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The voluntary informed consent of the subjects used in this research was obtained in accordance with AFR 169-3.

The Office of Public Affairs has reviewed this report, and it is releasable to the National Technical Information Service, where it will be available to the general public, including foreign nationals.

This report has been reviewed and is approved for publication.

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19. ABSTRACT (Continue on reverse if necessary and identify by block number) The universally voiced concern in the past regarding contact lens wear in aviation has been the fear of subcontact lens bubble formation. Previous reports have documented the occurrence of bubbles with hard PMMA lenses. Reported here are the results of contact lens bubble studies with soft hydrophilic and rigid gas-permeable lenses. Testing was accomplished in simulated aircraft flights in hypobaric chambers and onboard military transport aircraft. Hypobaric chamber flights were of 3 types: high-altitude flights up to 25,000 ft; explosive rapid decompressions from 8,000 ft to 25,000 ft; and 4-h flights at 10,000 ft. Transport aircraft typically had cabin pressures equivalent to 5,000 ft to 8,000 ft and ranged in duration from 3 to 10 h. For rigid gas-permeable lenses, central bubbles were detected in 2 of 10 eyes and occurred at altitudes greater than 20,000 ft. For soft contact lenses, bubble formation was detected in 22 of 92 eyes tested, and occurred at altitudes as low as 6,000 ft. Soft lens bubbles were located only at the limbus and were without sequela to vision or corneal epithelial integrity. Bubbles under the rigid lenses were primarily central, with potential adverse effects on vision and the corneal epithelium.			
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## SUBCONTACT LENS BUBBLE FORMATION UNDER LOW ATMOSPHERIC PRESSURE CONDITIONS

### INTRODUCTION

A concern for contact lens wear in military aviation has been the fear of subcontact lens bubble formation and the potential for subsequent physiologic and visual degradation. The quantity of a gas (i.e., nitrogen) that can remain dissolved in a solution--in this case, the precorneal tear film--is directly related to the absolute pressure. With increasing altitude, the atmospheric pressure drops off rapidly, reducing to one-half at 18,000 ft and to one-fourth by 34,000 ft. Pressure drops of this magnitude are likely in military aviation, and therefore the concern of subcontact lens bubble formation appears to be a valid one.

As early as 1944, Jaeckle (1) reported the incidence of subcontact lens bubble formation under scleral lenses at altitudes greater than 18,000 ft. Later, after many advances in contact lens fitting and design characteristics, Newsom et al. (2) reported bubble formation in 66% of the 16 polymethyl methacrylate (PMMA) corneal contact lens wearers they tested. Similar to Jaeckle's results, they reported bubble formation primarily at altitudes greater than 18,000 ft. They found that two subjects experienced blurred vision from formation of large bubbles under their contact lenses. They also found that the number and size of the bubbles varied with subject and altitude. Neither the PMMA lenses used by Newsom et al. nor the scleral lenses used by Jaeckle were permeable to gases such as oxygen or nitrogen.

Gas-permeable contact lens materials are available today in rigid or soft form. There are 4 general groups of gas-permeable rigid lenses: silicone and silicone-PMMA mixtures; cellulose acetate butyrate (CAB); and two new materials undergoing investigations, polystyrene and fluoropolymers. These rigid lenses are fitted within the corneal diameter with a back curve approximating the central corneal curvature. Lens centration is achieved by tear fluid forces, by the flattening of the peripheral cornea, and by the superior eyelid's holding the lens in place. In addition to the property of gas permeability through the lens material, a significant amount is also pumped under the lens on each blink. Soft lenses are made from a variety of different polymers, and most contain a large percentage of water (38%-79% by weight). The water contained in the soft lenses is the primary conduit for gas permeability through the lens (3). Soft lenses are larger than the corneal diameter, and fit on the eye by bridging the peripheral cornea and limbus, and rest on the central cornea and sclera. Unlike rigid lenses, little oxygen is pumped under the lens during blinking.

Reported here are the results of subcontact lens bubbles studies with rigid gas-permeable (silicone and silicone-PMMA mixture) and soft hydrophilic lenses. Accordingly, contact lens wear was evaluated as follows: simulated aircraft flights in hypobaric chambers ranging in altitude from 8,000 ft to 25,000 ft; during rapid decompressions from 8,000 ft to 25,000 ft; and onboard transport aircraft with cabin pressures equivalent to 5,000 ft to 8,000 ft.

## METHODS

### Rigid Gas-Permeable Lenses

We evaluated rigid gas-permeable lenses in a hypobaric chamber with a 25,000-ft-equivalent atmospheric pressure (Fig. 1). Ascent rate was 5,000 ft/min up to 8,000 ft and maintained for 30 min, then up to 25,000 ft and maintained for 30 min. Descent rate was also 5,000 ft/min, with 5-min stops every 5,000 ft.

Five subjects, from whom informed consent had been obtained, participated in the study. Each subject was tested in a minimum of two hypobaric chamber flights. Three subjects were successful wearers of rigid gas-permeable (silicone-PMMA mixture) lenses, and two were newly fitted with silicone rigid gas-permeable lenses. All subjects were successful daily wearers before being tested in the hypobaric chambers.

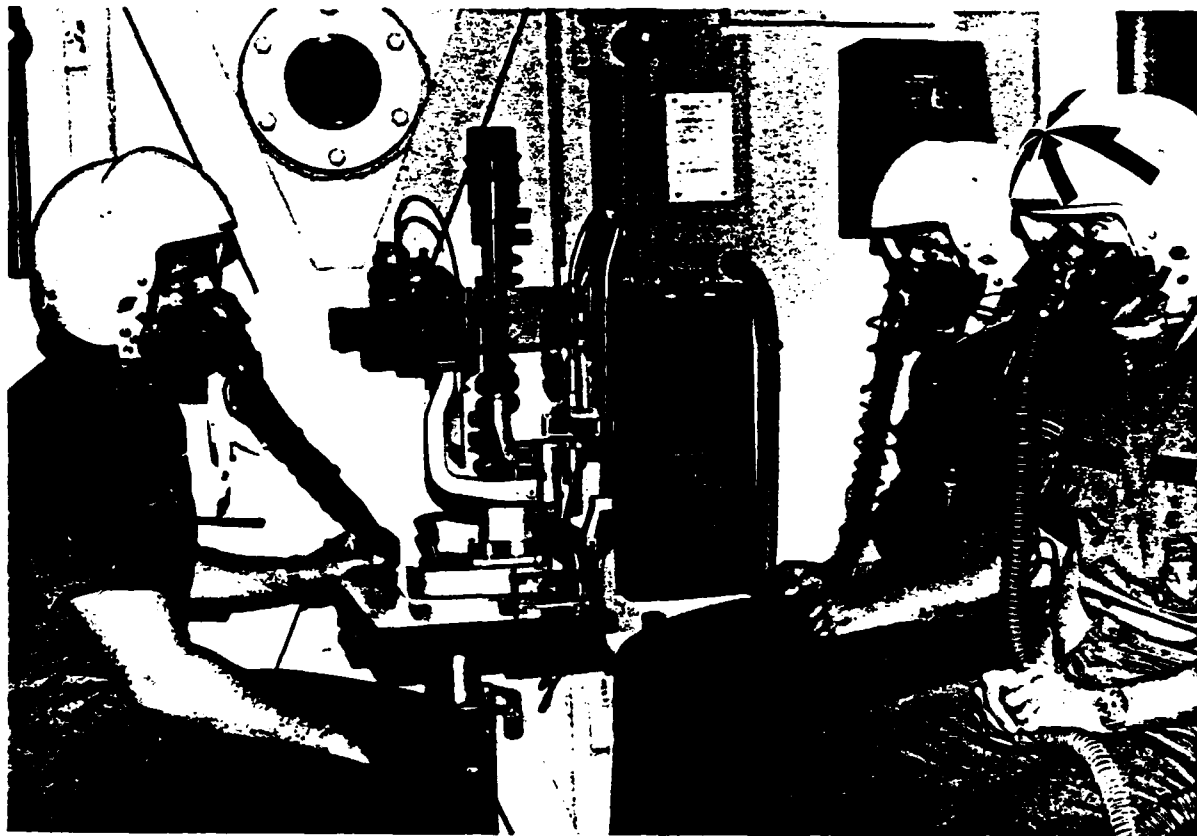


Figure 1. Testing in a hypobaric chamber at a simulated altitude of 25,000 ft.

We performed visual acuity measurements and slit-lamp examinations before, during, and after the chamber flights. The testing during the chamber flights was accomplished twice at 8,000 ft and 25,000 ft, and at every 5,000 ft during descent. Postflight slit-lamp examinations included the instillation of sodium fluorescein.

#### Soft Hydrophilic Lenses

A total of 46 subjects, wearing various soft lens polymers ranging from low to high water contents, were tested for bubble formation during a series of exposures to altitude. Testing was accomplished on simulated aircraft flights in hypobaric chambers and onboard military transport aircraft. Hypobaric chamber flights were of three types:

1. Eight subjects were tested on high-altitude flights at 25,000 ft with the same procedure as the rigid gas-permeable lens tests.
2. Ten subjects were tested in explosive rapid decompressions from 8,000 ft to 25,000 ft (Fig. 2).
3. Twelve subjects were tested during 4-h flights at 10,000 ft.

Thirty-four subjects were tested onboard transport aircraft flights with cabin pressures equivalent to 5,000 ft to 8,000 ft and ranging in duration from 3 to 10 h. Visual acuity measurements and slit-lamp examinations were performed before, during, and after the chamber and aircraft flights.

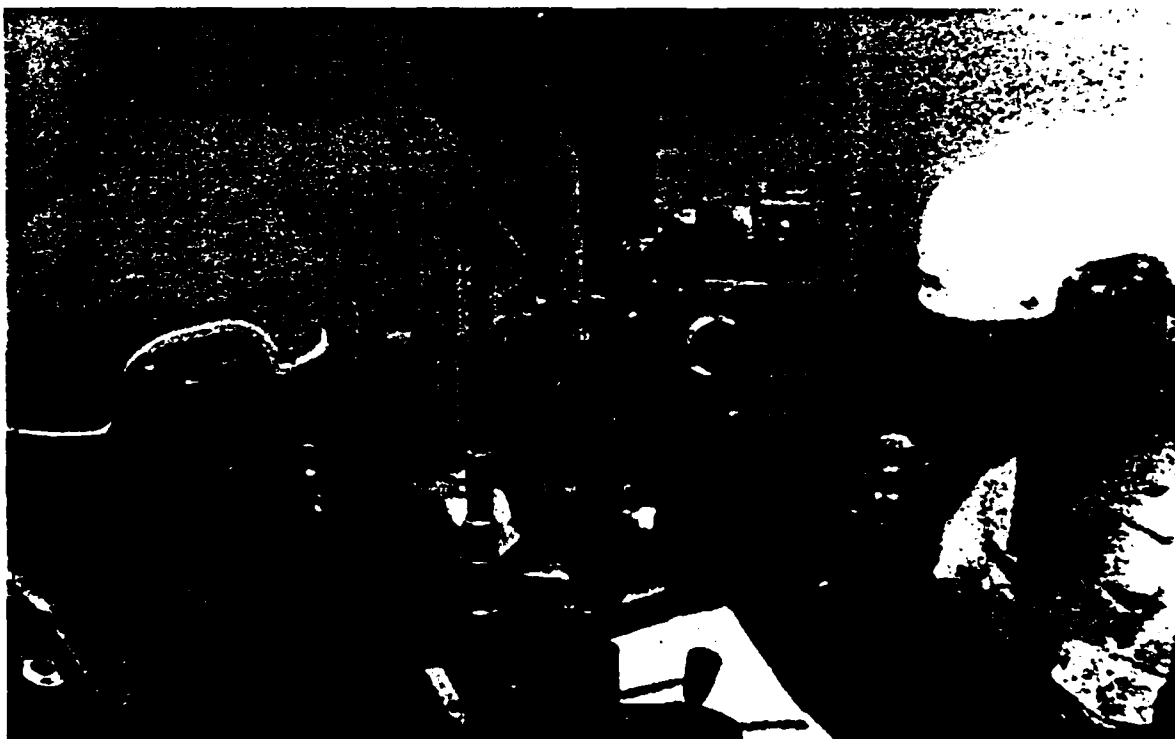


Figure 2. Explosive rapid decompression in a hypobaric chamber from 8000 ft to 25,000 ft.

## RESULTS

### Rigid Gas-Permeable Lenses

All subjects developed bubbles under the edge of their lenses at altitudes greater than 20,000 ft. These bubbles disappeared rapidly after the subjects blinked several times. Central subcontact lens bubble formation was detected in 2 subjects (Fig. 3). The bubbles were found in only one eye of each subject. One subject was wearing a silicone-PMMA polymer rigid lens and the other subject was wearing silicone rigid lenses with an aspheric base curve. In both cases, the bubbles were noted, at 25,000 ft, as many small ones, located centrally, that dissipated upon descent. Neither subject was aware of their presence, and visual acuity, as measured on a Bausch and Lomb Visual Test Apparatus, was unaffected. No damage to the corneal epithelium was detected in either subject.

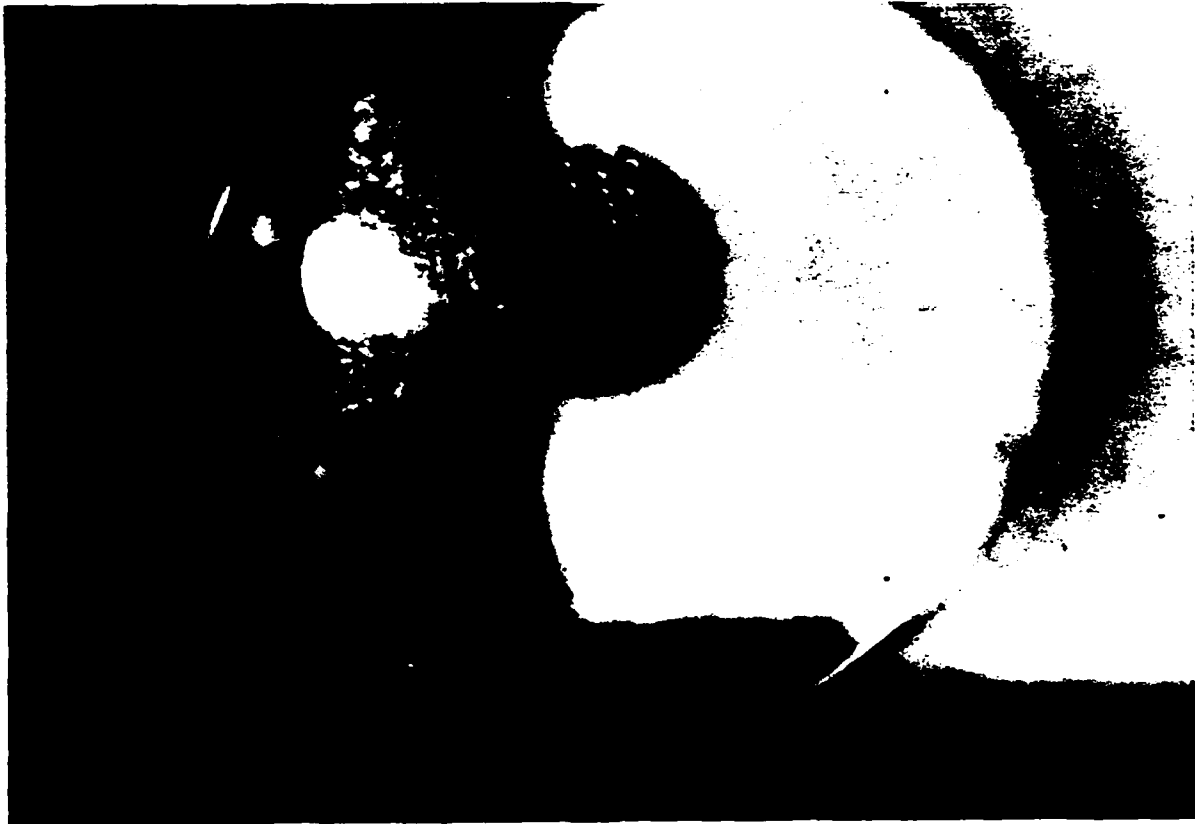


Figure 3. Central subcontact lens bubbles beneath a rigid gas-permeable lens at an altitude of 25,000 ft.

### Soft Hydrophilic Lenses

Subcontact lens bubble formation was consistently detected during the various hypobaric exposures, with an incidence of approximately 24% (a total of 22 of 92 eyes). In all cases, the bubbles were located only at the limbus (Fig. 4), none being detected over the central cornea. Bubbles were noted at altitudes as low as 6,000 ft and, once formed, would increase in size and coalesce with increasing altitude. The bubbles did not disappear with blinks, but dissipated over a several-minute duration. There was no effect on vision or corneal epithelial integrity, nor were any of the subjects aware of their presence.

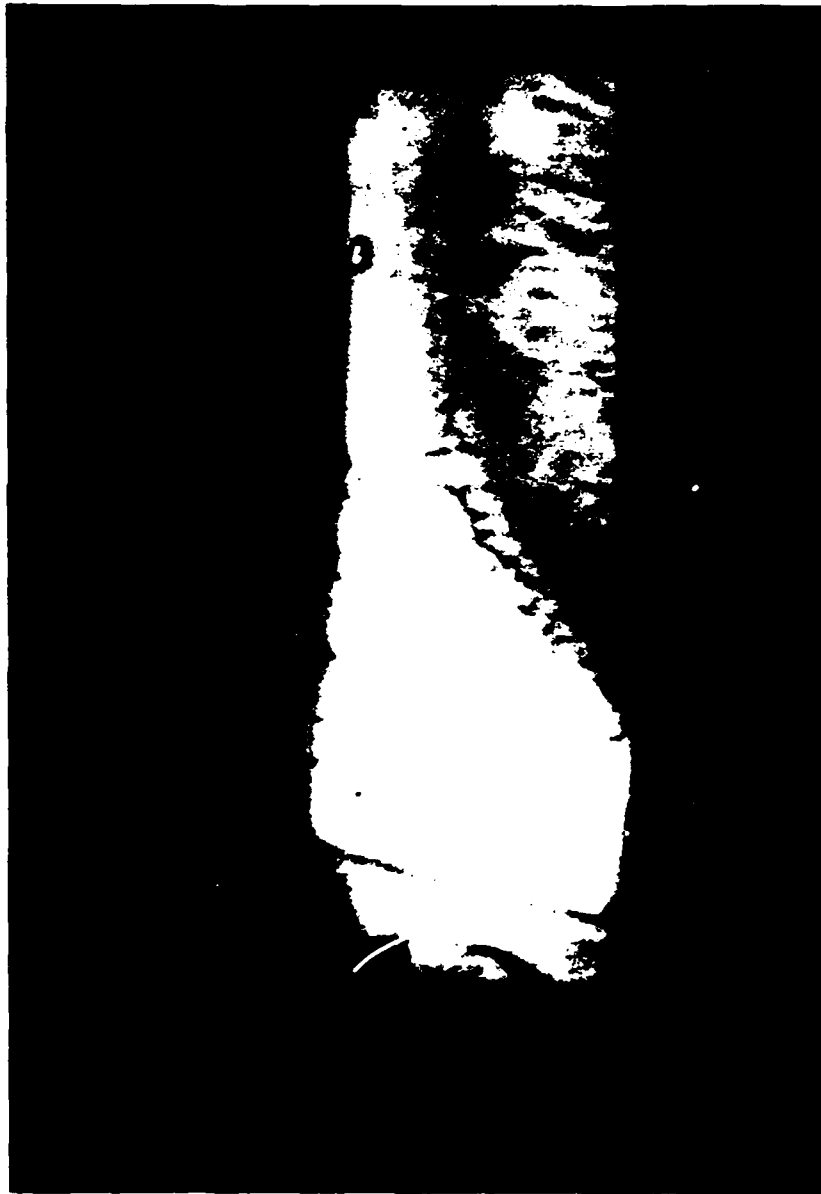


Figure 4. Limbal subcontact lens bubbles beneath a soft contact lens at an altitude of 25,000 ft.

## DISCUSSION

The quantity of a gas that can remain dissolved in a solution is directly proportional to its partial pressure and its solubility coefficient in a given medium (Dalton and Henry's Law). Even if a solution is supersaturated with a gas such as nitrogen, bubbles will not form unless the pressure differential is extremely large (4). However, small bubble nuclei that already exist in solutions can expand as the pressure decreases (Boyle's Law); and, if trapped by an impermeable or semipermeable membrane, may grow large enough to be observed. Bubble nuclei may be produced in areas of negative hydrostatic pressures, such as what may be produced from the contact lens tear pump.

The bubbles that formed under the gas-permeable lenses, both rigid and soft types, dissipated rapidly, whereas bubbles under PMMA lenses remained for longer durations (2). Additionally, the absence of bubbles in tear films of eyes not covered by a contact lens indicates that subcontact lens bubble formation may be purely a barrier problem related to the lack of or insufficient gas permeability of the contact lens polymer. Therefore, the occurrence of subcontact lens bubble formation and their duration would predictably be related to the overall gas transmissibility of the contact lens.

The previous investigations of nongas-permeable lenses (PMMA) indicate that the use of these contact lenses by individuals in hypobaric environments may cause visual degradation as the result of subcontact lens bubbles (2). Although central bubble formation was observed with rigid gas-permeable lenses, no resultant visual changes were detected. However, the rigid gas-permeable lenses were tested only to 25,000 ft, whereas the PMMA lenses were tested to 40,000 ft. Whether the bubbles that formed under the rigid gas-permeable lenses in this study would grow and coalesce at higher altitudes, as happened with the PMMA lenses, and would result in degraded vision remains for further study. For soft (hydrophilic) lenses, bubbles were detected in 24% of the eyes, but were located only at the limbus and were without sequela to vision or corneal epithelial integrity. Therefore, soft lens wear at altitude (e.g., in aviation or mountain climbing) should not be prohibited by the fear of bubble formation.

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