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**Temperature changes in contact lenses in connection with radiation from welding arcs**

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*Table 5.* Increase in temperature (°C) in free-hanging, wet contact lenses: A comparison between different welding methods. (MMA = manual metal arc, TIG = tungsten inert-gas, MIG = metal inert-gas)

| | Welding method | | | |
|---|---|---|---|---|
| | MMA | TIG 1 | TIG 2 | MIG |
| Lens temperature | | | | |
| Initial | 18 | 16 | 15 | 15 |
| Final | 53 | 21 | 24 | 32 |
| Increase | 35 | 5 | 9 | 17 |
| Air temperature | | | | |
| Initial | 21 | 20 | 20 | 20 |
| Final | 37 | 21 | 22 | 24 |
| Increase | 16 | 1 | 2 | 4 |
| Difference between final lens and air temperatures | + 16 | ± 0 | + 2 | + 8 |

The effect of a safety glass screen was also tested with all three types of lenses, a commonly used screen (DIN 10 A) being placed immediately in front of the eye and the thermocouple for air temperature measurement.

## RESULTS

### *Comparison between lenses*

The changes in the temperature (mean of two experiments) of the contact lenses and the surrounding air during 5 min of continuous radiation from MIG welding at a distance of 0.3 m are shown in table 4. The temperature increased 8—10°C more in all the strongly positive (thick) lenses than in the surrounding air; the negative, much thinner, lens showed a corresponding temperature difference that was only half of this.

### *Comparison between different welding methods*

The results of the welding method comparison, the changes in the temperature (mean of two experiments) of the lens and the surrounding air being recorded during 5 min of continuous radiation, are summarized in table 5 and fig. 1. A marked

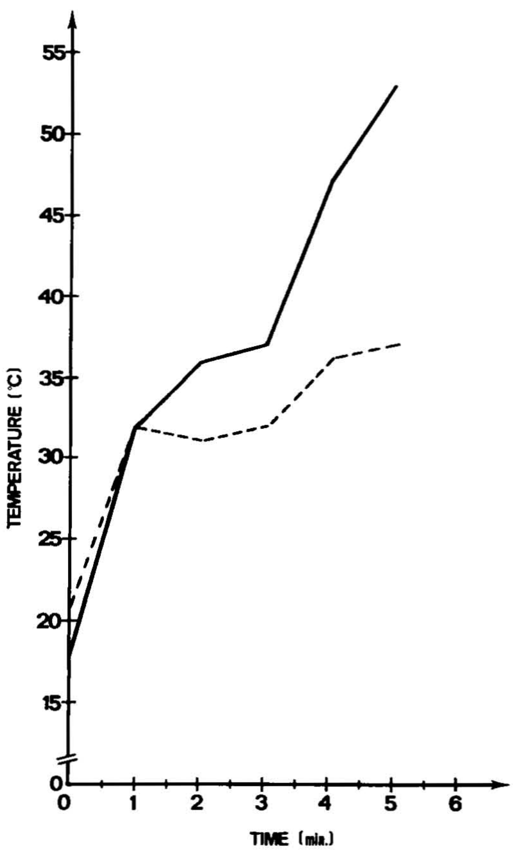


*Fig. 1.* Increase in temperature in a free-hanging, wet contact lens (———) and in the surrounding air (— — —) during manual metal arc welding. (Mean of two experiments)

rise in temperature occurred with MMA welding, and a moderate rise with MIG welding. In TIG welding the temperature changes were insignificant. The increase in lens temperature from 18 to 53°C during MMA welding is striking when compared with the increase in air temperature from 21 to only 37°C. The greatest rise occurred during the first minute, as can be seen from fig. 1. It should be noted that all lenses, although thoroughly wet at the start of the experiment, became completely dry during the MMA experiments.

*Temperature changes in contact lenses on rabbit eyes*

The temperature changes that occurred in the three types of lenses on rabbit eyes and in the surrounding air during radiation from 6.5 min of continuous MMA welding at a distance of 0.4 m are shown in table 6 and fig. 2. Considerable increases were noted. Whereas the air temperature rose only from approximately 23 to 30°C, the lens temperature increased from about 35 to 50°C. The highest lens temperature noted was 53° after 6 min. No important differences between the three lens types were found in these few experiments.

The chief rise in temperature of the surrounding air took place during the first 30 s. In the lenses the rise in temperature was also the fastest at the beginning of each experiment, the increase from 35 to 40°C taking 1 min (average) but that from 40 to 45°C requiring an additional 2.5 min (fig. 2).

During the course of the experiments most of the lenses dried out completely. Some remained in situ on the cornea, whereas many became deformed and dropped out of the eye. After two or three periods of welding, considerable corneal epithelial defects were seen.

The use of a safety glass screen (DIN 10 A) kept the temperature rise to a few degrees (fig. 3), there being little difference between the various types of lenses in this respect.

## DISCUSSION

*Comparison between different lenses*

In the first place it is highly interesting to note that although a fairly low energy welding process was used to compare the different types of lens material, the energy absorbed by the lenses was enough to cause a marked rise in temperature. This increase greatly exceeded the temperature change in the surrounding air. It was probably due primarily to relatively long-wave infrared radiation and secondarily to short-wave ultraviolet radiation, and absorption probably took place not only in

*Table 6.* Increase in temperature (°C) in contact lenses applied to rabbit eyes during manual metal arc welding without a safety glass screen.

| | Lens combination 1 (Mean of 2 experiments on 1 rabbit) | Lens combination 2 (Mean of 6 experiments on 2 rabbits) | Lens combination 3 (Mean of 3 experiments on 1 rabbit) |
|---|---|---|---|
| Lens temperature | | | |
| Initial | 35 | 34 | 35 |
| Final | 48 | 48 | 53 |
| Increase | 13 | 14 | 18 |
| Air temperature | | | |
| Initial | 24 | 23 | 24 |
| Final | 32 | 30 | 30 |
| Increase | 8 | 7 | 6 |
| Difference between final lens and air temperatures | + 16 | + 18 | + 23 |

the plastic material of the lens but also in the fluid in its pore system (5).

Although our comparison between lens types is rough, it indicates marked similarities between these types, provided they are of the same order of thickness. This result was to be expected since all the lenses were a soft, HEMA type, even though small variations in the chemical composition of the material may exist. The thinnest (a negative) lens showed a strikingly smaller temperature rise than the others. It is of course impossible to draw definite conclusions from an investigation as limited as the present one, but the thickness of the lens would appear to be more significant than the manufacturer. It should be recalled that a negative lens is thicker at the edge and ought to show greater absorption there. (The thermocouple was placed at or near the center of the lens.) Additional details of the comparison between different lenses can be obtained from our transmittance and absorption studies, published elsewhere (5), particularly with respect to hard contact lenses, which were not examined at all in the present temperature investigation. The type of hard lens analyzed with regard to absorption did not differ greatly from the soft lenses, however (5).

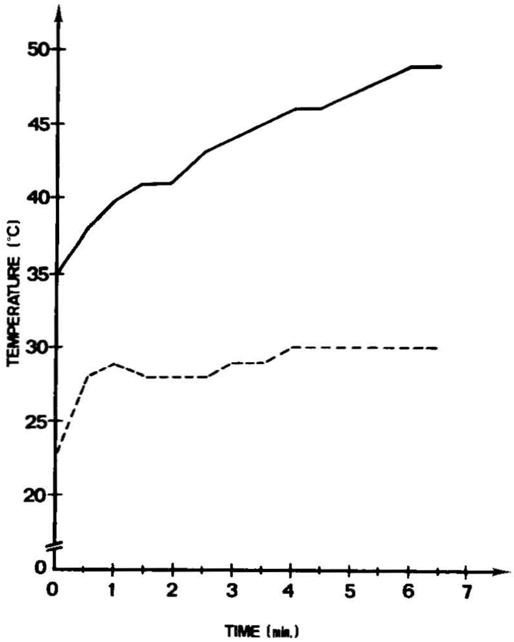


*Fig. 2.* Increase in temperature in contact lenses (———) applied to rabbit eyes and in the surrounding air (— — —) during manual metal arc welding without a safety glass screen. (Mean of 11 measurements on three lens combinations and three rabbits)

*Comparison between different welding methods*

Only three of the numerous welding methods in use were tested. MMA welding proved to be the riskiest, giving increases in temperature to over 50°C in certain cases. It seems to be significant that all lenses, despite thorough wetting before each exposure to an MMA weld, quickly dried out, and at the end of the experiment were completely dry. There is thus at least a potential risk that a lens might adhere to the eye and cause damage in connection with a temperature increase of this order. The investigation shows that great differences exist between different welding processes with regard to the temperature-raising effect of radiation on contact lenses. Because contact lenses show marked absorption within a wide range of the long-wave region of infrared radiation

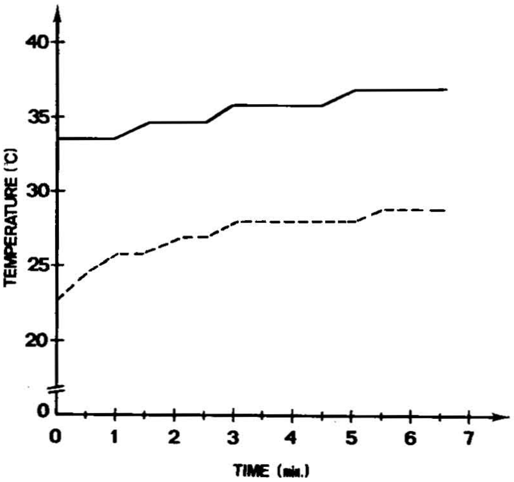


*Fig. 3.* Increase in temperature in contact lenses (———) applied to rabbit eyes and in the surrounding air (— — —) behind a safety glass screen during manual metal arc welding. (Mean of four measurements on three lens combinations and three rabbits)

and within the far short-wave region of ultraviolet light (5), welding methods with great emission within these regions are probably the most hazardous. It would therefore be of interest to carry out spectrophotometric investigations within a wide area of emission from different welding processes. With few exceptions (3) measurements hitherto carried out have embraced an all too narrow a spectrum to be of great interest in this particular connection.

*Temperature changes in contact lenses applied to rabbit eyes*

The striking increase in temperature to 50°C (average) which occurred in the lenses even when applied to rabbit eyes is a highly important observation. Most of the lenses dried during the course of the experiment, and many experiments had to be discontinued because the dry lens parted from the cornea and fell out. For example, one completely dry and consequently deformed lens fell out after 3 min at a temperature of 41°C. Obvious epithelial defects were noted after the completion of two to three periods of welding. It must be pointed out that no blinking took place in the anesthetized animals, so that the conditions of the experiment were not identical with work conditions. It cannot be excluded however that there is a potential risk for contact lenses to become adherent to the cornea on exposure to radiation. Such sticking is probably more serious than the actual rise in temperature. A significant observation made during the course of the experiments was that the rabbit corneal epithelium is much more resistant than the human one to mechanical trauma, both with regard to the strength of the surface and to the attachment to the base membrane. The risk of epithelial damage would therefore seem to be greater in man than in rabbit. Of course, no one would stare at an electric arc for several minutes at close quarters without safety glasses and without blinking. The powerful light acts as a warning and prevents this. A certain degree of hazard cannot be excluded, however, even when the gaze is directed away, if the radiation nevertheless falls on the contact lens. Also, only a very few welding methods have been examined so far, and other powerful sources of radiation, especially in the infrared region, may conceivably exist.

The mode of development of corneal lesions has been the subject of speculation in the literature. Fox (1) assumes that positive contact lenses cause convergence of the radiation and are therefore more likely to stick than negative lenses. This explanation seems highly unlikely. Instead, it is probably the thickness of the lens (and consequently also the fluid content) that primarily determines the degree of absorption and heat development.

The safety glass screen (DIN 10 A) tested in this investigation proved to afford efficient protection, the rise in temperature being only a few degrees. Other DIN protective filters recommended for electric welding are probably also satisfactory. (The transmittance of the DIN filters has only been measured to 4,000 nm, however.)

With regard to our methods it should be mentioned that certain fluctuations in the temperature, particularly of the surrounding air, took place because of difficulty in maintaining a constant arc.

In light of the findings that have so far emerged, we conclude that the wearing of contact lenses is not to be recommended in connection with at least certain types of welding unless safety glasses or screens are used. The lenses are liable to dry out and stick to the cornea. Furthermore, they do not prevent the development of keratitis photoelectrica (arc eye), as they transmit much of the ultraviolet region relevant in this connection (5). In other words, the lesion is the sum of two traumata. Admittedly, the one safety glass tested proved to afford protection against the rise in temperature in the lenses, but air pollution due to welding fumes, for example, constitutes yet another negative factor making the wearing of contact lenses highly questionable, even in combination with safety glasses or screens, unless these fit very closely. If a hazard analysis for each individual welding process is nevertheless considered necessary, the emission over a broad spectrum should be measured and related to the transmittance and absorption properties of the contact lenses (5).

Additional sources of radiation, especially within the infrared region, should also be investigated, for instance, steel furnaces. Another example is infrared heaters, which are capable of generating considerable energy and with which there is no bright, visible, warning light. Another study from our laboratory (4) shows that radiation from certain infrared heaters is capable of causing a much more rapid temperature increase in contact lenses than welding. Finally, the energy in arc flashes resulting from accidental flashovers in circuit breakers, e.g., in electric switch gears, even when of extremely short duration, may be very high indeed. Radiation of 250,000 $W/m^2$ during 1 s is said to raise the skin temperature from 25 to 50°C and is thought also to be capable of causing severe burns (2). Arc flashes in electric switch gears can generate radiation energy far exceeding this figure (2), and it would seem that, even when such flashes are very brief, they would be likely to increase the temperature of contact lenses with consequent adherence to the cornea. The accident referred to in the introductory paragraphs of this paper may thus have a perfectly reasonable explanation (8, 9), the safety glasses evidently providing inadequate protection in this case. In the event of an accident resulting in the adherence of contact lenses to the eye, we recommend that the lenses be thoroughtly wet before being removed.

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