Energy Radiance information for the Glassworker

NIOSH and OSHA have determined that the IR TLV (threshold limit value) to the unprotected eye is 10 mW/CM2 for time periods greater than 16 minutes. (10 mW is .010 Watts)

There are two critical areas to take into account when trying to determine the exposure value of IR radiation. The first critical area is the heat source, be it a furnace, glory hole, or torch. These heat sources typically run at a higher temperature than the glass being worked, and thus are a higher hazard. The second critical area is the piece being worked. The piece will typically have two zones, the heated area, or that portion of the piece that is currently being worked, and the rest of the piece, which is radiating at a lower temperature than the worked area. All three of these areas contribute to the total radiation that the glassworker is being exposed to.

The formula for Total Exposure is: A1 + A2 + A3, where Ax are the areas referred to above.

The formula for calculating portion exposure is: $R * (A / (2 * 3.14159 * r^2))$ Where R = Radiance of the object in watts per square centimeter, A = the area of the radiation, in square centimeters, and r = the distance to the eye from the heat source, in centimeters.

The following is an example calculation, based on a medium sized torch working a large borosilicate piece.

The flame calculation is this: For a 3500 degree flame (average), Radiance is 4 Watts per square centimeter. This may sound very low, but keep in mind that the blackbody calculations are based on the mass of item. A flame has very little mass for the amount of heat that it generates, which skews the Radiance calculations.

If the flame is one inch wide at the base and (for example) averages 8″ long, the area of the flame is 8 square inches, or 51.61 square centimeters. The distance of 16″ equals about 40 centimeters.

Plugging into the formula above, $E = 4 * (51.61 / (2 * 3.14159 * 40^2))$

Which reduces to: E = 4 * (51.61 / 10053)

Which further reduces to: E = 4 * .0051

Which results in: E = .020

The flame alone contributes 0.020 Watts per square centimeter at the eye.

For the working area, let’s assume that the temperature of the glass is 1800 degrees (which is a radiance of 10 Watts per square centimeter), and the area being worked is 5 centimeters by 10 centimeters (or 50 square centimeters). We’ll keep the same working distance of 40 centimeters.

E = 10 * (50 / 10053)

Which reduces to: E = 10 * .0049

Which results in: E = .049

The working area contributes 0.049 Watts per square centimeter at the eye.

For the nonworking area, let’s assume that the temperature of the glass is 1100 degrees (which is a radiance of 2 Watts per square centimeter), and the nonworking area equal to the working area, or 50 square centimeters). Remember that if you are building a large piece, the nonworking section will continue to grow, so keep that in mind. We will also keep the same working distance of 40 centimeters.

E = 2 * (50 / 10053)

Which reduces to: E = 2 * .0049

Which results in: E = .010

The nonworking area contributes 0.010 Watts per square centimeter to the eye.

Add these areas up, 0.020 + 0.049 + 0.010 and the result is 0.079 Watts per square centimeter to the unprotected eye.

Now, let’s figure the protection value of the various filters. Remember that the IR TLV is 0.010 Watts per square cm.

AVC AGW-203 passes an average of 3.4%, so 3.4% of 0.079 = 0.002 (20% of TLV)

AVC AGW-250 Shade 5 passes an average of 1.5%, so 1.5% of 0.079 = 0.0012 (12% of TLV)

The following is an example using a small torch similar to a Nortel Minor, and making a soft glass bead. The bead is two centimeters square, and in this case we will assume that because the bead is so small, that the entire bead is a consistent temperature.

If the flame is one half inch wide at the base and averages 6″ long, the area of the flame is 3 square inches, or 19.35 square centimeters. The distance of 16″ equals about 40 centimeters.

Plugging into the formula above, $E = 4 * (19.35 / (2 * 3.14159 * 402))$

Which reduces to: $E = 4 * (19.35 / 10053)$

Which further reduces to: $E = 4 * .0019$

Which results in: $E = .0076$

The flame alone contributes 0.0076 Watts per square centimeter at the eye.

For the working area, let’s assume that the temperature of the glass is 1200 degrees (which is a radiance of 8 Watts per square centimeter), and the area being worked is 2 centimeters by 2 centimeters (or 4 square centimeters). We’ll keep the same working distance of 40 centimeters.

$E = 8 * (4 / 10053)$

Which reduces to: $E = 8 * .0004$

Which results in: $E = .0032$

The working area contributes 0.0032 Watts per square centimeter at the eye.

Add these areas up, 0.0076 + 0.0032 and the result is 0.0108 Watts per square centimeter to the unprotected eye.

Now, let’s figure the protection value of the various filters. Remember that the IR TLV is 0.010 Watts per square cm.

Didymium passes an average of 66.7%, so 66.7% of 0.0108 = 0.0072 (72% of TLV)

AUR-92/ACE passes an average of 59%, so 59% of 0.0108 = 0.0063 (63% of TLV)

The following is an example using a small torch similar to a Nortel Minor, and making a borosilicate bead. The bead is two centimeters square, and in this case we will assume that because the bead is so small, that the entire bead is a consistent temperature.

If the flame is one half wide at the base and averages 6″ long, the area of the flame is 3 square inches, or 19.35 square centimeters. The distance of 16″ equals about 40 centimeters.

Plugging into the formula above, E = 4 * (19.35 / (2 * 3.14159 * 402))

Which reduces to: E = 4 * (19.35 / 10053)

Which further reduces to: E = 4 * .0019

Which results in: E = ..0076

The flame alone contributes 0.0076 Watts per square centimeter at the eye.

For the working area, let's assume that the temperature of the glass is 1800 degrees (which is a radiance of 10 Watts per square centimeter), and the area being worked is 2 centimeters by 2 centimeters (or 4 square centimeters). We'll keep the same working distance of 40 centimeters.

E = 10 * (4 / 10053)

Which reduces to: E = 10 * .0004

Which results in: E = .0040

The working area contributes 0.0040 Watts per square centimeter at the eye.

Add these areas up, 0.0076 + 0.0040 and the result is 0.0117 Watts per square centimeter to the unprotected eye.

Now, let's figure the protection value of the various filters. Remember that the IR TLV is 0.010 Watts per square cm.

Didymium passes an average of 66.7%, so 66.7% of 0.0117 = 0.0078 (78% of TLV).

AUR-92/ACE passes an average of 59%, so 59% of 0.0117 = 0.0069 (69% of TLV).

AGW-203 passes an average of 3.4%, so 3.4% of 0.0117 = 0.0004 (0.4% of TLV).

Commentary on the above calculation for small borosilicate work:

In light of the above calculations, it would be easy for a torch worker to assume that they don't need special eyewear to work with boro. After all, for a small bead, the standard soft glass filters seem to be blocking enough IR radiation, so that's ok, right?

Correct, but only so far as it goes.

There are two other issues that the torch worker needs to be aware of:

First is the assumption of relative flame size. In the given example, the flame is fairly small, in the Nortel Minor range. If you are using a larger torch or using a larger flame size than what is noted above, then the above calculations would need to be redone based on YOUR torch flame size.

The second assumption is that the only thing the torch worker needs to be careful of is IR. This is untrue. High Intensity Visual radiation, as referenced elsewhere discusses visible light "flares" across the visible spectrum that are in excess 10,000 lumens (1 lumen is a candle flame). 10,000 lumens is direct sunlight on a white sand beach.

HIV is present in working soft (especially the new silvered soft glass colors) and borosilicate glass, but is more pronounced in the boro colors. Boro colors contain higher levels of metal and mineral colorants, and as these metals and minerals burn off inside the flame, they emit visible light "flares" that can easily exceed 20,000 lumens. Additionally, anyone who fumes soft or borosilicate glass can be exposed to silver/gold "flares" that can exceed 30,000 lumens.

The recommendations that I made in that article still apply, no matter the size of the piece you are making:

Proper filter eyewear is an absolute requirement for anyone working with hot glass.

Clear lenses do not provide proper filtration of UV, HEV or HIV wavelengths and should not be worn during any hot glass operation.

Didymium and ACE (Amethyst Color Enhancement) filters by themselves provide safe filtration for soft glass workers but should never be used by borosilicate glass workers without additional visible light filters. If you have light colored eyes, you may wish to consider adding additional filtration depending on your personal sensitivity to bright light. Additional filtration may be required by anyone working with glass that contains silver additives or any other material that create bright visible light flares.

Individuals working colored borosilicate glass must always wear a shaded lens that provides a maximum of 10 to 12 percent visible light at the HEV wavelengths (which translates to a welding shade 3.0). Darker shades must be worn when working with glass that generates very bright visible light flares, such as quartz, or when working with metals such as silver or gold.

Ensure that your eyewear is providing proper filtration. Your supplier should be able to provide a transmission graph showing what your eyewear transmits at specific wavelengths.

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