Radiant Heat Resistance **& V-Gard® Visors**

Introduction

Controlling body temperature through workload and environmental management is critical in preventing heat-related illnesses. According to the Occupational Safety and Health Administration (OSHA), it is difficult to predict just who will be affected [sic: by heat] and when, because individual susceptibility varies.[1] However, workers in foundries, steel mills, bakeries, smelters, glass factories, furnaces, and other elevated temperature working environments are particularly vulnerable due to frequent exposure **to thermal radiation and the electromagnetic radiation (EMR) it produces.**

Personal Protective Equipment (PPE) designed for use in hot working conditions, such as reflective-coated visors, are one of the engineering controls[2] used to reduce the physical demands of heat on a worker. However, these visors are often mistakenly used for the sole purpose of preventing heat stress. It is important to note that where indicated, reflective-coated visors can also help to prevent skin and eyes from absorbing EMR.

Sources of EMR give off varying levels of energy across a range of wavelengths, including visible light, infrared (IR) and ultraviolet (UV) radiation. IR and UV can adversely affect soft tissues such as eyes (see "EMR: UV, IR and Potential Effects" for more details).[3]

CAREFUL! IT'S NOT THAT HOT!

Stating extremely high protection levels for reflective-coated visors is inaccurate, and could be dangerous! The stated "protection levels" likely represent the temperature at a heat source. However, as radiant energy moves through space—say from a blast furnace to a worker—much of the heat energy is dispersed as it travels. Assuming the worker is at an appropriately safe distance from a furnace, the temperature at his face is likely lower than the temperature at the heat source.

Common Misconceptions

Marketplace confusion is often caused by inaccurate information about the performance of reflective-coated visors. Consider this information found on the web on reflective coated visors:

- *"…Gold coated shields can protect against radiant temperatures up to 1,800° F."*[4]
- *"[SIC: Faceshields provide]…up to 2000° F and higher (radiant heat temperature)."*[5]
- *"… Provides 65% infrared transmittance."*[6]

The first two bulleted statements could cause misuse of PPE and potential harm to the wearer[7]. The information in the third bullet is simply wrong: IR transmitted through the visor could potentially cause eye and skin damage.

Compounding the issue, perhaps, is the fact that OSHA has a Non-ionizing Radiation (29 CFR 1910.97) standard that **excludes** safety requirements for select types of EMR[8], including visible, IR and UV radiation.[9] Additionally, under ANSI/ISEA Z87.1-2010, American National Standard for Occupational and Educational Personal Eye and Face Protection Devices (the "Standard"), there are no requirements for heat resistance or IR reflectance, so there is no way to substantiate and compare claims about these performance criteria.[10]

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1 *OSHA Technical Manual (OTM), Section III, Chapter 4, "Heat Stress." Effective January 20, 1999.*

2 *Engineering controls are those measures put in place to eliminate or reduce workplace hazards through the use or substitution of engineered machinery or equipment.*

3 *UV radiation hazards may also be found in these environments. This paper briefly addresses information on UV hazards and how V-Gard Visors address those. However, UV measurements were not conducted as part of the investigation.*

4 *http://www.elvex.com/FAQ-face-protection.htm#Heat.*

5 *Oberon bulletin "Face-Fit™ Faceshields (Cat#: Shield 2000).*

6 *http://solutions.3m.com. Refer to PN 82602-00000.*

7 *These high temperatures are likely temperatures at the heat source, and not the heat getting to the visor and/or wearer.*

8 *OSHA provides technical guidance on optical radiation for welding and lasers.*

9 *The American Conference of Governmental Industrial Hygienists (ACGIH) has developed Threshold Limit Values (TLVs) for IR and UV. Additionally, ANSI/ISEA Z87.1-2010 provides requirements for UV, visible light transmission, and welding/IR filters for specific wavelengths. Both the TLVs and the Standard are considered by OSHA to be National Consensus Standards for these types of hazards.*

10 *The Standard provides requirements for welding and infrared filters, including exact product markings required for specific filtering claims.*

Dispelling the Myths

In an effort to help our customers better understand the performance of V-Gard Visors, the MSA Chemical Research and Materials Science team conducted *"Radiant Heat Resistance"* investigations on several types of V-Gard Visors (*See Table 1*). These experiments were conducted in our ISO 9001: 2008 research and development facility, the John T. Ryan Memorial Laboratory. The investigation evaluated several types of V-Gard Visors for heat distortion and the effects of irradiance[11] on the visors.

The purpose of these evaluations was twofold: 1) determine the amount of heat in the front of the visor vs. what the eyes/face would experience behind it; and 2) measure the amount of irradiance (the rate of transfer of EMR) at the eye to understand how much EMR was getting under the visor. A summary of the results are presented in this paper.

Test Method

MSA *"Radiant Heat Resistance"* investigations were conducted using a radiant heat test apparatus which was designed and constructed according to ASTM E162 (Standard Test Method for Surface Flammability of Materials Using a Radiant Heat Energy Source); see *Figure 1*.

Figure 1: *Laboratory Set-Up with Assembly in Test Position*

Each V-Gard Visor was assembled in the "as worn" position using a VGard Slotted, Elevated Temperature Frame (with debris control) and an MSA Thermalgard® safety cap (*see Table 1 for all MSA products tested*).

Each assembly was donned on a headform, with the center of the visor facing toward the center of the radiant panel. The temperature at the center of the radiant panel was measured by an OMEGA® Nextel ceramic-insulated thermocouple. The irradiance applied to the outer surface of the visor was measured with a Schmidt-Boelter heat flux sensor.

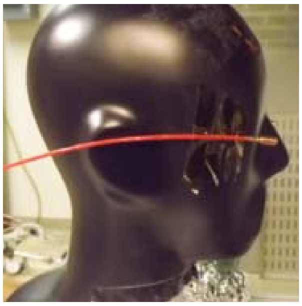


Figure 2: *Irradiance Measurement (by the) Eye*

The temperatures at nose and eye locations of the headform were measured with OMEGA® thin film flux sensors equipped with a thermocouple. The irradiance by the eye of the headform was measured with a thermogage circular foil heat flux transducer (*Figure 2*). All tests were conducted at an ambient temperature of 72°F (± 5°F) [22°C, ± 3°C] and relative humidity of 50% (± 25%). All digital outputs of heat flux and thin film flux sensors were collected as a function of time of exposure using LABVIEW design software.

Test Assembly	Visor Description, PN	Stated Use	Frame Description, PN	Helmet Description, PN
1	V-Gard, Clear Reflective-Coated, PC Molded Visor, 9.5" x 17.75" x .07" (241 x 451 x 1.8 mm), for use in radiant heat, elevated temperature environments (P/N 10177690)	Elevated Temperatures & Radiant Heat	V-Gard Slotted Elevated Temperature Frame w/debris control (P/N 10115821)	White Thermalgard cap with Fas-Trac Ratchet Suspension (P/N 486960)
2	V-Gard, Clear, PC Molded Visor, 9.25" x 18" x .098" (235 x 457 x 2.5 mm), for use in non-radiant heat, elevated temperature environments (P/N 10115846)	Elevated Temperatures (not for radiant heat)	Same as Assembly 1	Same as Assembly 1
3	V-Gard, Green Tint, PC Molded Visor, 9.25" x 18" x .098" (235 x 457 x 2.5 mm), for use in non-radiant heat, elevated temperature environments (P/N 10115849)	Elevated Temperatures (not for radiant heat)	Same as Assembly 1	Same as Assembly 1
4	V-Gard, Shade 3 IR, PC Molded Visor, 8" x17" x .07" (203 x 432 x 1.8 mm) for welding (P/N 10115859)	Welding, up to Shade 3	Same as Assembly 1	Same as Assembly 1
5	V-Gard, Shade 5 IR, PC Molded Visor, 8" x17" x .07" (203 x 432 x 1.8 mm) for welding (P/N 10115861)	Welding, up to Shade 5	Same as Assembly 1	Same as Assembly 1

Table 1: *MSA Products Tested*

11 Irradiance is the rate at which EMR energy is transferred per unit area incident on a surface.

Heat Distortion and V-Gard Visors

Table 2, below, shows the temperature on the surface of each visor, as well as under the visor (at the nose and eye) for each assembly. All visors in Table 2 were exposed to an irradiance of 9.5 kW/m^2 on their respective surfaces. **(For comparative purposes, fire fighters are typically exposed to radiant heat fluxes between 5-10 kW/m^2 during a fire.)** All assemblies were tested for 220 seconds at a distance of 9.5" between the visor and a 1460° F (793° C) heat source.

The data in Table 2 illustrates that reflective-coated visors are significantly better at keeping susceptible areas of the head cooler than visors which are not reflective-coated.

To demonstrate just how well V-Gard Reflective Visors are able to resist heat, *Graph 1* shows the temperature behind the visor (at the nose and eye) for the reflective visors only. The visors were exposed to three different levels of irradiance on the visor surface (9.5, 15 or 20 kW/m^2). All visors in Graph 1 were tested for 9.5" from a heat source of 1460° F (793° C) for 250 seconds.

Even as the irradiance more than doubles and the temperature on the outside surface of the visor increases, the temperature under the reflective-coated visors remained fairly constant across similar irradiances. Clearly, though, that length of exposure and irradiance level have an adverse effect on the temperature felt at the eyes and nose.

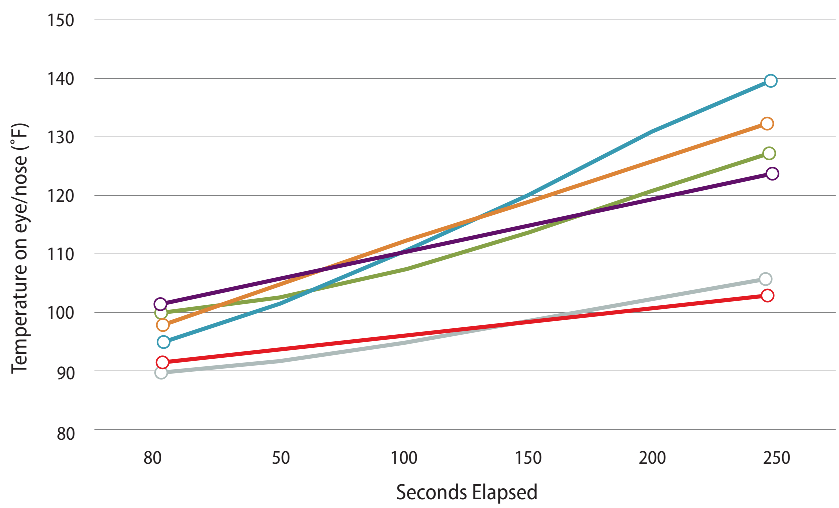
Keep in mind, there is no indication that these temperatures are safe for a worker. Common heat stress management practice is to avoid heat disorders by ensuring that deep body temperature does not exceed 100.4° F (38° C). Additionally, when the temperature of the skin reaches 113° F (45° F), humans feel pain and tissue damage occurs.[12] A worker who becomes uncomfortable may experience "heat aversion" (*i.e., turn away*) in such situations, but there's no guarantee. An increase in irradiance level (as the graph shows), or exposure time, or a decrease in distance to the heat source, substantially increases the chance for over-exposure to heat. This is why MSA believes it's misleading to state these types of visors provide protection at temperatures anywhere near 2000° F (1093° C)!

Test Assembly	Description	Temperature of Visor Outer Surface	Temperature Under Visor, Near Nose	Temperature Under Visor, Near Eye
1	V-Gard Clear, Reflective-Coated Visor	414.3° F (212.4° C)	106.3° F (41.3° C)	103.7° F (39.8° C)
2	V-Gard Clear Visor	431.2° F (221.8° C)	147.2° F (64.0° C)	135.3° F (57.4° C)
3	V-Gard Green Tint Visor	419.9° F (215.5° C)	160.1° F (71.2° C)	154.8° F (68.2° C)
4	V-Gard Shade 3 Visor	487.5° F (253.1° C)	167.2° F (75.1° C)	158.9° F (70.5° C)
5	V-Gard Shade 5 Visor	433.7° F (223.2° C)	173.6° F (78.7° C)	167.8° F (75.4° C)

***Table 2:** Temperatures on Visor Outer Surface and Nose/Eye Locations. Data reflects the average across all trials.*

Graph 1 Key

- 9.5 kW/m^2 (nose)
- 15 kW/m^2 (nose)
- 20 kW/m^2 (nose)
- 9.5 kW/m^2 (eye)
- 15 kW/m^2 (eye)
- 20 kW/m^2 (eye)



***Graph 1:** V-Gard Reflective Coated Visors at varying levels of irradiance Data reflects the average across all trials.*

12 Note: temperature reported as Celsius (45C + 1 C) in original work; authors of this paper provided conversion of the U.S. audience. Nachum Dafny, Ph.D., Department of Neurobiology and Anatomy, The UT Medical School at Houston (http://neuroscience.uth.tmc.edu/s2/chapter06.html)

EMR: UV, IR and Potential Effects

Optical radiation is the portion of the EMR spectrum comprised of UV, IR and visible light wavelengths (*see Figure 3, "Electromagnetic Spectrum"*). While our study did not include an investigation into the effects of UV and IR specifically, it is important to understand where there is EMR, these hazards exist.

The biological effects of UV radiation depend on the wavelengths concerned. UV spectrum has a wavelength shorter than that of visible light but longer than an X-ray and is categorized based on intensity: UV-A (315 nm to 400 nm), UV-B (280 nm to 315 nm) and UV-C (100 nm to 280 nm). UV-C is generally dissipated in the atmosphere, and seems to have little damaging effect. UV-A and UV-B can have damaging effects on exposed soft tissues, such as skin and eyes. For example, exposure to UV A/B accounts for 90% of the symptoms of premature skin aging[13]. Cataracts, macular degeneration and photokeratitis (a feeling of sand in the eyes) can all be attributed to overexposure to UV light.[14]

A common misconception is that all polycarbonate blocks UV. This is not the case. The Standard provides transmittance requirements for UV filters for eye and face protectors, and defines UV as, "Electromagnetic energy with wavelengths from 200–380 nanometers."

Under the latest Standard, if UV filtration claims are made by a manufacturer, applicable UV filtration markings must be placed on product. For maximum protection across a broad wavelength spectrum, look for products that are marked with "U6." With few exceptions, most V-Gard Visors offer an "U6" marking.[15]

IR also has a range of wavelengths, with near IR (or IR-A, 700 nm–1400 nm) having shorter wavelengths and therefore higher energy. Skin exposed to IR usually provides a warning mechanism against thermal effect in the form of pain (heat aversion). Eyes, on the other hand, may not experience heat aversion. Since the eye may not detect IR, blinking or closing the eyes to help prevent or reduce damage cannot be relied upon to protect the worker.[16] And since waves are short (but not hot), the internal temperature of the eye is raised—essentially "baking" it. Medical studies indicate that prolonged IR exposure can lead to lens, cornea and retina damage.[17] One investigation conducted by a U.S. government agency in a steel manufacturing facility showed that the potential existed for employees to be over-exposed to IR radiation, up to 30 feet (9.1 m) from the source.[18] To help protect against longterm IR exposure, workers can wear products with IR filters or reflective coatings.

The Standard provides requirements for welding and IR filters used for protection from very specific wavelengths of IR. Working conditions that generate EMR can be dark; they can also lend themselves to potential IR exposure across varying, uncontrolled wavelengths. When both higher light transmission and a broader approach to IR protection is needed, a visor that provides IR reflectance (rather than filtration such as a shade IR visor would provide) should be considered.[19] The Standard does not provide requirements for IR reflectance, so there is no way within the Standard to substantiate claims that visors "reflect IR."

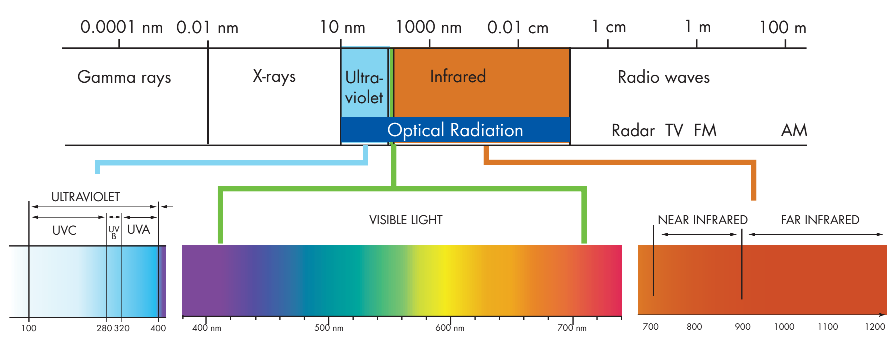


Figure 3: *Electromagnetic Spectrum*

13 Heather Brannon, MD, "Effects of Sun on the Skin: Cellular Skin Changes Caused by UV Radiation", About.com Dermatology, March 23, 2007

14 Gary Heiting, OD, "Ultraviolet (UV) Radiation and Your Eyes", All about Vision, July 2012.

15 To confirm UV protection on a V-Gard Visor, please check the actual V-Gard Visor for an "U6" mark.

16 An exposed person may blink(i.e., "aversion") if the IR is accompanied by a light flash of sufficient intensity.

17 "Radiation Effects on the Eye, Part 1 – Infrared radiation effects on ocular tissue, Optometry Today, 1999.

18 National Institute for Occupational Safety and Health (NIOSH), HETA 89-364-2202.

19 The performance of any product can vary based on conditions of use (such as subjection of the material to different environmental conditions, the assessment of usability by the wearer, etc.). For these reasons, MSA recommends that proper PPE should be selected for use and application by the site safety specialist, whose responsibility it is to ensure that hazards, communication of instructions, precautions and limitations are conveyed and observed.

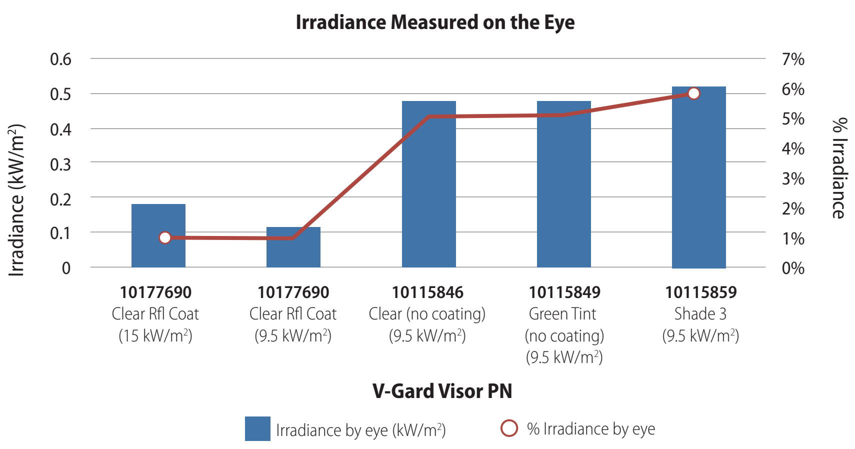
The European Standard (EN166, 7.3.3), does, however. An optional mark under EN166 ("R") requires manufacturers to certify claims of "enhanced reflectance in the infrared." V-Gard Reflective-Coated Visors have an "R" mark. An "R" mark on a visor signifies that the mean spectral reflectance of IR between 780 nm–2000 nm (i.e., the amount reflected from the protector) is >60%. To help ensure accurate claims of IR reflectance, either use products with an EN166 "R" mark, and/or request certification/test data for IR reflectance claims from the visor manufacturer.

Irradiance and V-Gard Visors

The Internal Commission on Non-Ionizing Radiation Protection recommends for environments >95° F (35° C), that ocular irradiance levels should not exceed 0.1 kW/m² for lengthy exposures (>1000 s); however, higher irradiance levels could be sustained for shorter periods.[20] To better understand the potential hazards from sources emitting IR radiation, The National Radiological Protection Board commissioned a study where irradiance (λ >770 nm) was measured in various glass and metal manufacturing facilities. With an assumed exposure period of 10 s for each identified activity, measurements ranged from 0.0008 kW/m² (~18 ft [5.5 m] from an electro-refining control room)[21] to 0.17 kW/m² (~6.5 ft [2 m] from a furnace port).

To simulate a hot working environment, each V-Gard Visor shown in *Graph 2* was subjected to the irradiance on the visor surface as indicated (either 15 kW/m² or 9.5 kW/m²) by placing it 7" (178 mm) or 9.5" (241 mm) respectively, from a heat source of 1460° F (793° C) for five (5) minutes. Measurements were taken under the visor, near the eye.

The left graph axis shows the actual irradiance levels, while the right axis shows the percentage of irradiance measured by the eye. V-Gard Reflective-Coated Visors were superior in lowering irradiance over non-coated clear, tinted or shade IR visors. Even at the higher irradiance level of 15 kW/m², the reflective-coated visor outperformed the other three visors.



Graph 2: *Irradiance Measured by the Eye*

Graph 2 shows an interesting phenomenon. The Shade 3 (IR) visor exhibited a lower level of performance at lowering irradiance levels. Based on laws of physics, even at a white-hot temperature (2000 K), 99% of the energy is in the infrared. Intuitively, the performance seems at odds with the purpose of Shade IR visors. One hypothesis to explain this performance is the filtration mechanism (i.e., the dye used to filter the IR) actually prevents the thermal radiation from going through the visor, absorbing it either in the material and/or on the surface of the visor. Eventually, the visor melts as it "super-heats," becoming soft and pliable–as the temperature of the material exceeds its "glass transition temperature." It is for this reason that the Shade 5 IR visors were not shown in the Graph – they reached a temperature which exceeded their glass transition temperature before the test exposure time of 5 minutes was reached.

20 Internal Commission on Non-Ionizing Radiation Protection, "Guidelines on Limits of Exposure to Incoherent Broadband Optical Radiation," 1997.

21 Whilock, MJ, Pearson, AJ & Walker, SG (HSE), "Measurements of the visible and infrared emissions from the industrial sources at eight industrial sites in the UK," HSE Contract Research Report No. 77/1996 for the National Radiological Protection Board, 1996.

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Conclusion

There are several key findings from this investigation:

- V-Gard Reflective Coated Visors reduced the temperature on the outside of the visors vs. what was measured at the nose and eyes (400° F+ (204° C+) vs. slightly >100° F (38° C), respectively). Two important caveats to this finding:
  1) While these visors may have withstood temperatures much higher than 400° F (204° C), the temperature under the visor a worker experiences would likely exceed common industry understanding of "safe levels." In other words, although the visor itself may not be adversely affected, the person wearing it could be.
  2) Most assemblies (helmet and frames) to which these visors attach should not be worn in radiant heat exceeding 275° F (135° C)–350° F (191° C) (depending on the MSA helmet to which the frame attaches). While helmets can be altered by the wearer to prevent damage to them, neither the helmet nor frame are performance-tested, per the Standard, to temperatures beyond those stated by MSA.

TESTED FOR COMPLIANCE

V-Gard Elevated Temperature Frames are made of glass-filled nylon. Aside from the obvious dielectric and weight benefits nylon provides, V-Gard Frames are tested to withstand 350° F (177° C). This is the maximum temperature MSA safety helmets intended for use in radiant heat, such as Skullgard®, are exposed to prior to impact testing after heat exposure. While this investigation showed the V-Gard ET Frames can withstand higher temperatures, MSA does not recommend exposure to higher temperatures to ensure compliance and performance of the helmet to which they are mounted.

- V-Gard Reflective Coated Visors prevent a significant amount of irradiance from reaching the areas under the visor, such as eyes and face. From this finding, it is easy to see why it's important to select the proper visor for the temperature, distance and duration of/from an EMR source.
- EMR consists of UV and IR, so these hazards should be carefully considered when selecting PPE. Visors tested and marked for proper protection levels against such hazards should be selected. If such markings are not readily available on the product, test data should be secured to ensure claims have been substantiated.

PPE, such as reflective-coated visors, are one of the engineering controls used to reduce physical demands of heat on a worker. When inaccurate information about the performance of reflectivecoated visors (including radiant heat protection levels) exists in the marketplace, misconception could arise about the role these visors play in preventive safety measures—and, these could prove dangerous to workers. Reflective-coated visors should not only be able to distort heat, but they should also reflect IR and filter UV.

To help prevent potential injuries and conditions related to hazards present in hot working environments, product markings and information must be carefully considered, and then substantiated through Standards and/or accurate test results, made readily available to safety professionals who can accurately compare product performance and select the product that's right for their working conditions.

Definitions

Electromagnetic Radiation (EMR). *A form of energy emitted and absorbed by charged particles which exhibits wave-like behavior as it moves through space.*

Irradiance. *The rate at which electromagnetic radiation (EMR) energy is transferred per unit area incident on a surface.*

Infrared (IR) Radiation. *A type of EMR a range of wavelengths, with near IR (or IR-A, 700 nm–1400 nm) being the closest to visible light, and "far infrared" closer to the microwave region.*

Optical Radiation. *The portion of the EMR spectrum that consists of infrared radiation, visible light and ultraviolet radiation.*

Ultraviolet (UV) Radiation. *A form of EMR with high frequency waves shorter than that of visible light but longer than an X-ray (100 nanometers [nm] to 400 nm) and is categorized based on intensity: UV-A (315 nm to 400 nm), UV-B (280 nm to 315 nm) and UV-C (100 nm to 280 nm).*

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