Light guide technology: using light to enhance safety

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ABSTRACT

When used to detect extreme temperatures in harsh environments, warning devices have been placed at a distance from the "danger zone" for several reasons. The inability to mix electricity with flammable, caustic, liquid or volatile substances, the limited heat tolerances exhibited by most light sources, and the susceptibility of light sources to damage from vibration, have made the placement of a warning light directly within these harsh environments impossible. This paper describes a system that utilizes a beam of light to provide just such a warning. This system can be used with hard-wired or wireless sensors, side-light illumination, image projection and image transfer. The entire system may be self-contained and portable.

KEYWORDS

Fiber Optic, Light Guide, Warning, Alert, Sound, Visual Display, Sensor, Temperature, Safety, Heat

LIGHT GUIDE TECHNOLOGY

There are many situations that require a device to warn of extreme temperatures. These may be temperatures that are set by the user, or they may occur accidentally. In either case, they may pose a danger to those using the equipment, those in the immediate vicinity, or to the equipment itself. Ideally, such a device, or system, must be durable, readily visible, and impervious to the immediate environment. When working with sensitive equipment, unexpected deviations in temperature can signal imminent fire, explosion, or equipment failure. Historically, product designers and engineers have been limited in both the types of warning devices available, and in the placement of a chosen device, or symbol for the viewer to see.

Although there are any number of warning lights, and audible alerts available, their use is hampered by the limitations imposed by their construction. The use of Light bulbs, LED's and other sources of illumination are limited by their ability to tolerate excessive sustained temperatures, and/or excessive or sudden temperature spikes. Standard incandescent bulbs are an unsuitable in situations where they may be subject to excessive vibration, electromagnetic fields, and caustic or harsh chemicals. With a short life span, they cannot be used in areas where access is problematic. Incandescent bulbs also emit heat, which has the potential for creating additional problems.

Light emitting diodes (LED's) are transistors- not true light bulbs. Although their serviceable life of an LED is significantly longer, it has a maximum operating temperature that is as low as 284º F.

The inability to mix electricity with flammable, caustic, liquid, or volatile substances has prevented the placement of a warning device directly in the area of greatest need- directly in the danger zone The system described in this paper can have the light source located at a remote location, away from the potential danger zone. Isolating the light source from the harsh or extreme environment protects the functionality of the system.

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The pioneering and patented technology described in this paper makes it possible to place warning device or symbols near, or at, the point of use. Utilizing a beam of light and a light guide, engineers and designers can illuminate a symbol that warns of excessive temperature. The temperature may be the result of design or malfunction. Excessive temperature may be defined as any temperature- hot or cold, that is not the set or desired temperature.

The patented work creates a system that utilizes a beam of light to provide a warning, indicating excessive temperature. Because a beam of light can safely pass through hostile or extreme environments, the problems outlined above are easily circumvented, allowing a warning device to be placed in the area of greatest need.

The warning can take many forms:

The warning can be in the form of any symbol (word, graphic, character)

Using image projection or image transfer, the warning can be projected directly onto the danger zone

For example, the word "HOT" can be projected directly onto a hot surface. The light source can be maintained at a safe distance from the heat, still providing the warning at the point of greatest danger

The brightness or intensity of the warning light can be coordinated to the temperature

The warning can take the form of a" heads-up" projection like those in many automobiles and airplanes

The visual warnings outlined above may be combined with an auditory warning device as well. Just as the intensity of the warning light can correlate with the temperature, so too, can the volume of an auditory warning. Conversely, there are times when an audible alert will not suffice. Imagine, a noisy factory floor. Will the added sound of a warning system be easily noticed? In these situations, the possibility of using a visual alert exponentially increases the possibility that the warning will be noted and heeded.

The warning symbol can also take the form of an automated illuminated symbol. It could drop down into the field of vision as needed. This would produce a binary effect of safe/ unsafe. The automated mechanism would be similar to the small screen in the overhead area of an airplane's cabin that drops down to inform passengers of the placement of the emergency exits etc. This also allows for a hidden safety system, if aesthetics dictate design.

The system created with these patents can be used with any temperature sensing system. The sensors can be hard-wired or wireless. The sensor can be a battery powered, non-contact, infrared temperature measurement device. These inexpensive sensors have a range of greater than 40 feet. Such devices are sensitive to temperature ranging from -328º F to 1999º F (-200º C to 1372º C). The system can be used with multiple nodes or motes. It can also be any combination of hard wired or wireless detection systems. In areas of extremely limited space the warning symbol can be reflected or relayed from one location to another before arriving at the end point. This is particularly helpful when adding this technology to existing equipment, as a retrofit. If there are obstacles, the light is simply reflected to avoid them and reach the end point of the warning.

The system can be dual purpose. It can be used for general illumination, but if there is a dangerous situation the "white" general illumination, turns red indicating the warning. An example would be 3M's light tubes. These light guides are used for general or decorative illumination. They provide uniform illumination over great lengths. Their white light can instantly turn red to warn of the excessive temperature situation. All that is required is a second red light source or a red filter in front of the light source, changing the color of the ambient light. This makes for a very efficient and financially viable adaptation of an existing system. Such a system is used in subways for general illumination. If a fire should occur, the system can instantly change color and alert occupants of the danger from the heat of a fire in the vicinity.

The initial research and development efforts focused on thermochromic technologies (color-changing inks, dyes, resins). Although it was felt that these technologies held great promise, they failed to deliver on that promise. Thermochromics are unable to withstand high temperatures and are UV sensitive. The ability to change color and provide a warning was hampered by the slow reaction time of these inks. With time, the thermochromics degrade, and render them all but useless.

As the efforts to improve safety advanced, light was used as a means for providing the warning. Both fiber optic cable and light guides were able to bring the warning through the extreme environments to the user, but they too, had problems. Commercially available heat resistant fiber-optic cable is limited to approximately 650º F, slowed the transmission of light, is sensitive to bending, and is very costly. The use of solid rods presented additional problems: They could not be bent to transmit light properly; they also slowed light transmission, and added unnecessary cost.

A contact burn will occur in only one second at 167°F (75°C). Most people, however, have the perception of a burn (pain), at 130°F (approx. 54°C). The goal became clear: to develop a warning system, that would work "instantly", be safe to use in extreme environments, and finally- be cost effective., and easily implemented as a new system, and as a retrofitted system.

The concept was continually refined until, ultimately, the need for the fiber-optic cable was eliminated altogether. Fiber-optic cable is composed of a series of glass fibers encased in a tube. When the fiber is removed, a simple tube remains. The beam of light can travel through that empty space. The " tube" prevents the light from being visible along its route, eliminating "light bleed," until it reaches the end point.

The jacket, itself, can have a pattern cut along its length providing illumination along the path of the "cable". An opaque light guide can also transmit this side light illumination. This could create a series of warnings or one solid illuminated red line.

The next innovation was the elimination of the empty jacket. This allowed a focused beam of light to illuminate the symbol. The light can easily pass thru most areas, which makes retrofitting easier. State of the art safety can be easily added to the oldest potentially dangerous equipment.

The light source can be varied. Examples are an incandescent bulb, LED, or laser. If the light's path is not direct and needs to bend, it can be reflected off of a mirror, or any other reflective surface, and guided to the desired end point. When the chosen application is heat sensitive, LED's are ideal.

It is important to emphasize that this is not merely theoretical. This warning system can be constructed using technology and products that currently exist, and will not require arduous and expensive research and development. Adding this warning system to an existing product can be accomplished using existing technology.

The technology covered by these utility patents is not limited to a particular product or use, but for the purpose of this presentation, it is helpful to look at how the technology can be applied to a single product- the gas cooktop.
Currently, there is no system to warn of potentially dangerous residual heat on a gas cooktop. The burner caps and grates of a gas cooking appliances remain hot long after the flame is extinguished, without any visual clue. Although there are crude warning systems built into electric cooktops, there has never been an attempt to create a similar warning device in a gas-powered cooking appliance. This technology allows a warning device to be placed directly in the center of the gas cap, at the heat source.

Traditionally, there were three main impediments to creating this type of warning device. From a safety perspective, it was not desirable to pass electrical wiring through an area with flammable gases. Even if it were possible to wire a light source in this area, such wiring would adversely affect the flow of gas through the burner cap, negatively impacting the gas distribution and making it difficult to create a consistent heat source. Finally, light bulbs and LEDs cannot withstand the direct and reflected heat produced by the burner, which can exceed 1200°F (approx. 649°C), especially in commercial settings.

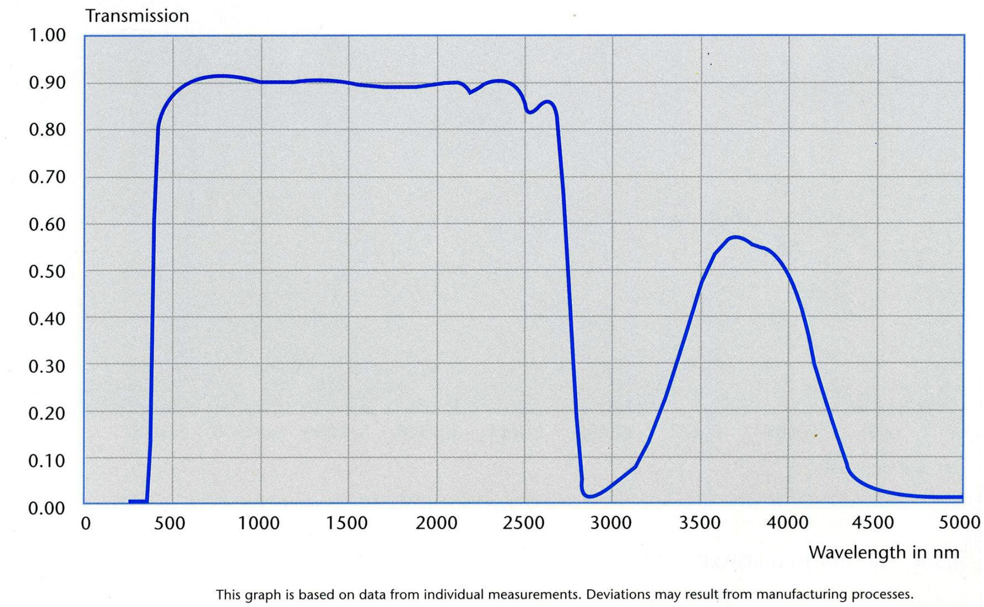
Using the method described in these patents, a warning light can be placed in the center of the gas distributor cap. A red LED, positioned beneath the cooktop, will direct a beam of light through a clear glass ceramic disc that is flush mounted in the bottom of the gas distributor unit. The LED is held in place by a temperature-resistant adhesive. The beam of light passes through the slug and gas (which is clear, and residue free), and illuminates a second flush-mounted glass ceramic disc in the center of the cap. The surface of the top slug is “sanded” to catch the light. It also makes the product scratch resistant. Subsequent minor scratching only assists in light capture.

Placement of the warning light in the gas cap is the most dramatic for illustration purposes, but it is not limited to that position. The patents offer the end-user unlimited possibilities for placement, shape, size, brightness, color, symbol, and design. The beam of light can be projected from the area directly below the cap or it can be offset, coming from the side of the cap as well. With the use of a light guide, the beam can be sent in any direction. While any glass ceramic material can be used, the material cited in the example above is Robax by Schott Home Tech North America. This material is available in various stock sizes such as 3, 4, and 5 mm. It is clear and can be easily machined. In some forms, bends, curves, and angles are possible.

The optical properties for a stock 3-mm-thick round slug with a 10-mm diameter are represented in Figures 1 and 2. The human eye cannot discern the difference between light traveling through air and light traveling through Robax. Keep in mind that typical uncoated glass reflects approximately >8% of the light back.

Optical properties

Transmission ROBAX®, 3 mm



Transmission ROBAX®, 3 mm, in UV range

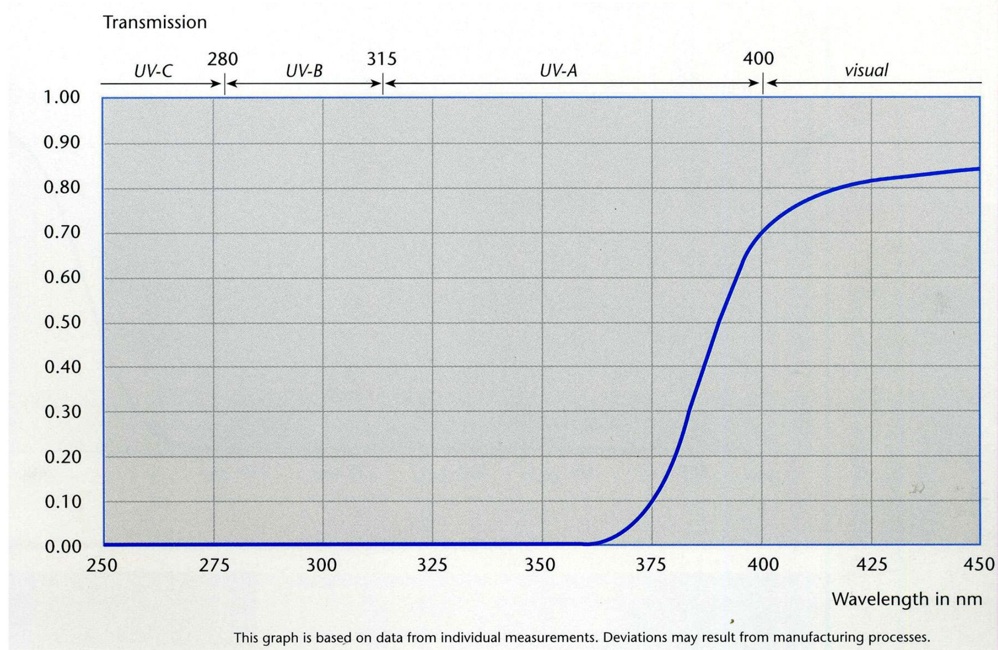


Figure 1 (top). Optical properties for a stock 3-mm-thick Robax material.
Figure 2 (bottom). Optical properties, UV range, for a stock 3-mm-thick Robax
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The temperature tolerance range for clear glass ceramic is –400° to 1400°F (–238°C to 760°C). However, the light guide can be any clear material, from simple plastic to the glass ceramic. The choice of material will depend on its location and the temperatures involved.

The need to warn of excessive temperature is not limited to situations where a high temperature can cause injury. There are times when the desired temperature is exceedingly low, and any upward trend presents a possible danger. Liquid hydrogen needs a storage temperature of 252º F. If, for example, the storage container reaches 220º F, this exceedingly cold temperature is still too warm, so a warning is needed.

Technology Possibilities

Expanding on the basic theme of using light to project a warning presents several additional possibilities. In addition to using the beam of light to directly illuminate a symbol (red dot, stop sign, etc.), the light can be projected through a danger zone with the projected symbol serving as the warning. The surface temperature is not relevant if the symbol is projected directly onto it. A surface may reach 3000º F or higher. The surface may also be a liquid in stable or agitated state. The material may transition as the temperature increases, or conversely, harden as it cools. A visual alert it is not a problem as long as the light can be seen when projected on it, and has an illuminated symbol projected on to it.

As mentioned earlier, the path the light takes can be controlled with the use of light guides—simple hollow tubes used to direct the light to its intended target. The light guide can also take the form of a flexible rope. A flexible cable can be rolled and stored so that it is accessible for emergency situations. The warning can be projected from the end, or the side of the cable. The rolled and stored cable can be paired with a self-contained, self powered light source, a battery powered non-contact infrared “point and shoot” temperature sensor and an audible component to become a self-contained, easily transportable unit. Obvious advantages are that up to 80% of the safety system’s cost can be due to the “hard wiring” of the system—a portable system as described mitigates much of that cost. During a power failure or blackout, this is an ideal warning system. The “rope” can quickly cordon off a dangerous area, producing a visual field to be avoided, with an auditory warning.

Conclusion

The Patented technology offers engineers, product and systems designers a virtually blank slate to design excessive temperature warning systems. The warning can be audible, visual, or both. The system can indicate status, malfunction, deviation, or any information concerning temperature or environmental change. The system can be hard wired, wireless or any combination of the two.. The warning can end at a single point, or multiple points on a surface, using one light source. The warning symbol can be projected from a light guide to any surface when traditional warning lights would fail due to extreme temperature. The system is also easily maintained due to the fact that the light source is at a distant location, and can be placed at an easy point for service or bulb replacement.

Safety is paramount. Bulbs fail, and wires melt at extreme temperatures. These patents allow an engineer or designer to incorporate a safety system in any environment for any unexpected temperature deviation.

REFERENCES

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