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ABSTRACT

The extraordinary market growth of the high power halogen torchiere (halogen uplighter) presents significant global energy savings opportunities for energy efficient alternatives. Extensive development of prototype designs of energy efficient torchiere systems using compact fluorescent lamps (CFLs) has lead directly to the production and commercialization of CFL torchieres. This paper analyzes the current global market for torchieres and compares the electrical and photometric characteristics of one of the new CFL torchieres to standard tungsten halogen torchieres. Power assessments and photometric data indicate that the new CFL torchiere provides significant energy savings over the standard tungsten halogen torchiere while producing more luminous flux. The energy savings is jointly due to the high source efficacy of the CFLs and the poor performance of many cheaply made halogen lamps. Laboratory and in-situ experiments indicate that the CFL torchieres use 65 Watts to produce 25 percent more light than the 300 W tungsten halogen torchieres they are designed to replace. Additionally, the CFL torchieres have the benefit of a cooler lamp operating temperature, making them safer luminaires (Brooks, 1997; New York Times, 1997). This safety benefit, coupled with the potential for significant reductions in global greenhouse gas emissions, has prompted the insurance industry to form a unique alliance with energy conservation groups to promote energy efficient torchieres.

INTRODUCTION

The 300 to 500 W halogen torchiere (halogen uplighter) is ubiquitous in many countries in residential lighting applications. The high wattage of these systems has contributed to a very significant increase in residential lighting loads, in many cases undermining more than a decade of energy conservation programs aimed at increasing compact fluorescent lamp (CFL) market penetration (Calwell, 1996; Jennings, 1997).

Developing alternatives to the halogen torchiere and advancing their market penetration represents one of the largest lighting efficiency initiatives in recent years due to the torchiere's high wattage and universal application. Researchers at the Lawrence Berkeley National Laboratory (LBNL) have developed high-efficacy prototypes using a broad range of CFL sources and electronic ballasts that match (or exceed) the light output and distribution of halogen torchieres. These prototypes offered the manufacturing community early concepts for utilization of both existing and novel, high efficacy sources.

One of the LBNL prototypes (seen in Figure 1) uses two CFL lamps in combination with a single electronic ballast. This torchiere design is now being produced by a major U.S. manufacturer. This new design increases the torchiere's fixture efficacy from less than 12 lm/W to nearly 65 lm/W. Specialized optics and lamp positioning resulted in a fixture efficiency of approximately 84 percent. This value is fairly high considering the relatively large size of the light sources compared with the fixture. With this efficiency, the prototype exceeds the lumen output of

currently marketed 300 W halogen torchieres. This lumen matching capability was considered critical, particularly in the first phases of the market transformation, as to not jeopardize consumer satisfaction with the products.



Figure 1: An example of a CFL Torchiere based on LBNL prototypes that is now available in the marketplace. The luminaires are similar in look to halogen torchieres, but they use two fluorescent lamps in a white reflector dish (as seen on right).

While assisting manufacturers to bring these new efficient designs to the marketplace, LBNL researchers also worked with other interested parties to ensure there would be a market for these new luminaires. This effort included cooperative demonstration projects with numerous U.S. universities to relight their student dormitories, coordination with utility groups to assist in their demand side management (DSM) programs, and collaboration with the insurance industry to reduce greenhouse emissions as well as fire related risks.

This paper first describes the large and growing worldwide market for halogen torchieres. Next, the performance of a high-efficiency CFL torchiere is compared to the halogen luminaire it is intended to replace. Finally, the unique market transformation effort involving the insurance industry is discussed in some detail.

INTERNATIONAL TORCHIERE SALES TRENDS

It is estimated that there are 40 million halogen torchieres in the U.S. at this time with an additional 15 to 20 million units in annual sales (Calwell, 1996). Low cost coupled with high output, quality lighting has made this luminaire extremely popular across the residential and university dormitory sectors. It is not unusual to see 80 to 90 percent of college dormitory rooms

with a torchiere as the primary light source. The energy used by these inefficient luminaires is estimated to have completely offset the energy savings of all the installed CFLs in the U.S.

Other data suggest that in many industrialized countries the pattern is similar to that in the U.S., whereas in developing countries the products have not yet entered the market place or are just beginning to do so.

The only detailed national survey yet conducted was in the Netherlands (Kavelaars, 1997). It revealed that 25 percent of Dutch households own torchieres, with an average of 1.6 in these households. Notably, about 8 percent of all households had two or more torchieres. Approximately 3 million units have been sold to-date.

In France, about 7 million halogen torchieres have been sold since their introduction in the early 1980s. In 1990, sales peaked at 1.5 million units/year - about one for every 13 households. Sales growth has also been meteoric there, rising at 200 percent per year until the products represented 10 percent of all residential fixtures sold and as much as 80 percent of the dollar value of retail lighting fixture sales (Calwell and Mills, 1996).

In Sweden, torchiere sales increased over the last two years, but exact sales data are not available. A limited number of fluorescent alternatives are available, but are aimed primarily at the high-end commercial marketplace. Countries like South Africa appear to be seeing halogen torchieres on the shelf for the first time, where about 150,000 units have been sold to date. New Zealand and Australia, in spite of their proximity to the manufacturing centers of Asia, have not yet been active markets for torchieres (Calwell and Mills, 1996).

Exact sales numbers for Italy are not available, but sales saw a significant decline after 1990 as the market became saturated (Borsani, 1996). Sales also began to decline in France around this time (Menanteau, 1996). Torchieres were slower to catch on in the U.S., but a surge of inexpensive imports from Asia forced prices down in the mid-1990s resulting in several years of very rapid sales growth. Sales then leveled off and declined recently due to market saturation and a series of news stories about torchiere fire hazards and high energy cost.

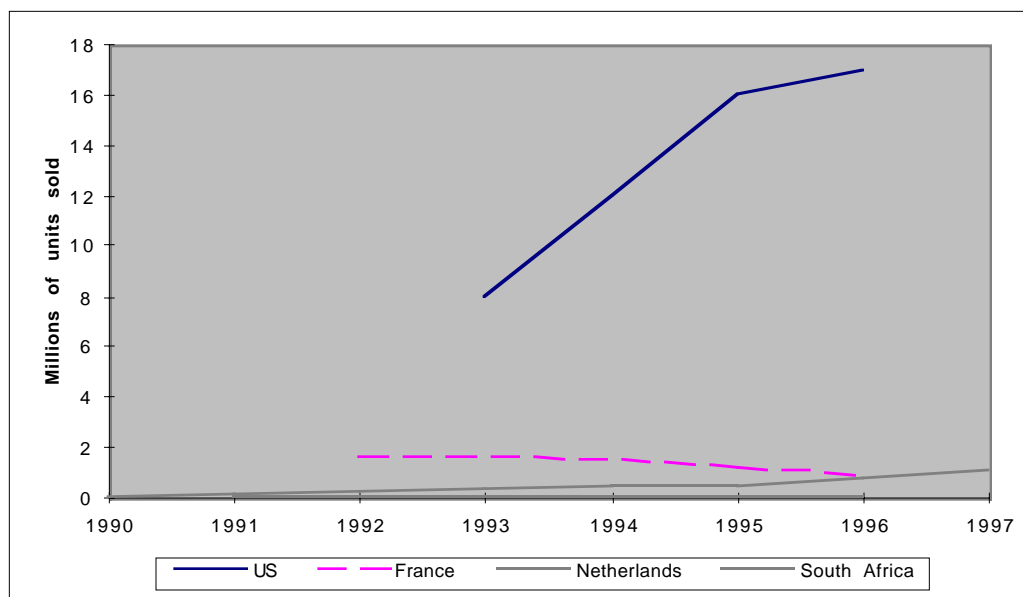


Figure 2: Halogen Torchiere Market Data for Various Countries

THE INEFFICIENCY OF HALOGEN TORCHIERES

Halogen torchieres represent a threat to energy efficient lighting not only because their market is so expansive, but because they are also much less efficient than earlier assumed. During a CFL torchiere demonstration program and “lamp swap” at Stanford University, nearly 100 of the halogen light sources from the halogen torchieres the students turned in were collected and brought back to LBNL for measurement. This data was then applied to known torchiere fixture models to obtain information on luminaire distribution and output and yield information on the in-situ electrical and photometric characteristics of halogen torchieres.

The 300 W halogen lamps that were collected were separated into two groups: (1) “Unlabeled”, which included all unlabeled and labeled lamps of unknown manufacturers, and (2) “Known”, which included all labeled lamps from known manufacturers in Europe, the United States, and Japan.

Table 1 presents the photometric and electrical results broken down into several categories: unlabeled 300 W lamp , known 300 W lamps, all 300 W lamps, and all 500 W lamps.

<u>Lamp Type</u>	# of Lamps	% Lamps	Nominal Wattage	Measured Wattage	Lumens	lm/W
Unlabeled	60	69.0%	300	272.0	3684	13.54
Known	12	13.8%	300	304.0	6251	20.56
Total 300 W	72	82.8%	300	277.4	4109	14.58
Total 500 W	15	17.2%	500	476.5	9372	19.58

Table 1: Electrical and Photometric Data on Halogen Lamps from Stanford Dormitories

Unlabeled lamps were found in 69.0% of the torchieres while, overall, 300 W halogen lamps were found in 72 of 87 (82.8%) of the torchieres. Because the unlabeled lamps are generally much cheaper than known lamps, they not only come in most or all torchieres, but are often used as replacement lamps as well. Unfortunately, these lamps dramatically underperform compared to the known lamps. The unlabeled lamps averaged 3684 lumens compared to 6251 lumens from the known lamps. The known lamp average efficacy of 20.56 lm/W represents more than a 50 percent improvement over the unlabeled average efficacy of 13.54 lm/W. The unlabeled lamps generally operated 10 percent below their rated power.

Figure 3 presents a bar distribution graph of 300 W lamp data broken into 1 lm/W bins. The first peak on the histogram occurs from 12 to 15 lm/W and is comprised entirely the unlabeled lamps. The second peak occurs at 21 lm/W, slightly higher than the common “catalog” efficacy of halogen lamps of 20 lm/W, and is made up exclusively of the known lamps. Also noteworthy are the lamps with efficacies of 10 lm/W and under. Many of these lamps were heavily blackened on the inside, possibly caused by prolonged operation in a dimmed operation mode.

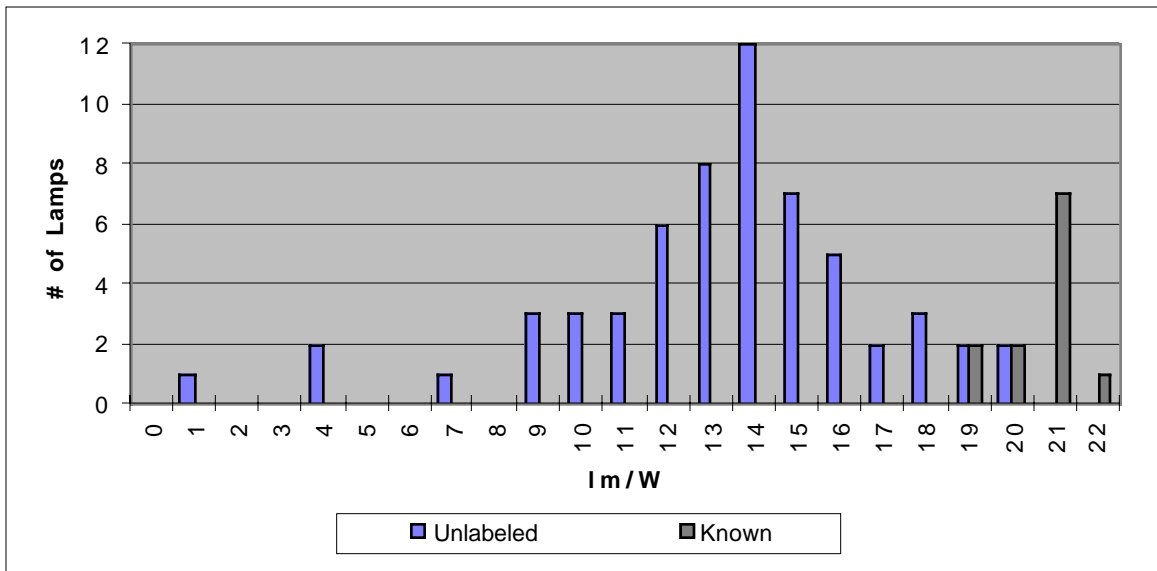


Figure 3: Lamp Efficacy Distribution by Lamp Group

Further decreasing the energy efficiency of the halogen lamps is the strong non-linear relationship between efficacy and dimming, as seen in Figure 4. This plot, constructed from average data of several halogen lamps, shows that a halogen torchiere operating at 50 percent light output consumes nearly 75 percent of peak power, while at 50 percent peak power the torchiere produces 20 percent of peak light output (Page and Siminovitch, 1997).

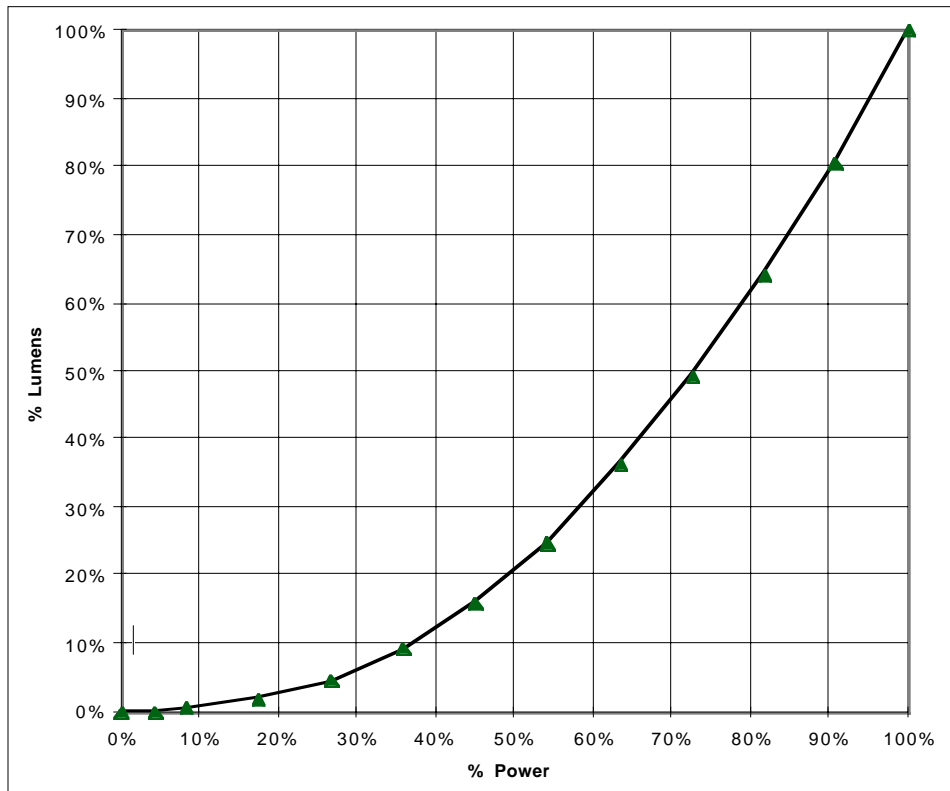


Figure 4: Percent lumen vs. percent power for dimmed halogen sources.

CFL TORCHIERES BETTER AND BRIGHTER

Table 2 presents lamp and fixture data for the CFL torchiere and the average unlabeled halogen torchiere at full and half power. All CFL data is from integrating sphere and goniometric measurements, while the halogen lamps' power and lumens are found by placing average lamp data in the fixture model.

	Nominal Wattage	Actual Wattage	Lamp Lumens	Fixture Efficiency	Fixture Lumens	Power Factor	Harmonic Distortion	Fixture Efficacy
CFL - Full	72	64.95	4826	83.7%	4041	0.99	14.33%	62.21
CFL - Half	36	39.12	2565	83.1%	2132	0.95	25.88%	54.50
Halogen - Full	300	272.0	3684	88.0%	3242	0.99	5.37%	11.92
Halogen - Half	150	136.0	739	87.7%	648	0.63	75.41%	4.76

Table 2: Fixture Data from CFL and Halogen Torchieres

At full power, the CFL torchiere produces 25 percent more lumens than the average 300 W halogen torchiere and has over five times greater efficacy. At half power, the CFL torchiere produces over six times the lumens of the halogen torchiere at half power, with a 13 fold increase in efficacy. While the poor performance of the halogen lamps contributes to this efficacy discrepancy, it should be noted that even if the halogen lamps averaged their “catalog” efficacy of 20 lm/W, there would still be a three to four fold efficacy improvement in going from halogen to CFL torchieres. It should also be noted that the power quality (power factor and harmonic distortion) of the halogen torchiere decays fairly dramatically with dimming, whereas power quality is fairly constant for the CFL torchiere. (The harmonic distortion of the halogen at full power is non-zero because of the presence of the dimmer switch.)

The distribution of the CFL torchiere is best understood when analyzed relative to the halogen torchiere. Figure 5 gives the averaged candlepower plot for the CFL torchiere and the typical 300 W torchiere at full and half power. While, at full power, the halogen torchiere nearly matches the centerbeam intensity of the CFL torchiere, the halogen torchiere has a much more narrow distribution. At half power, the decreased efficacy of the halogen caused by dimming is quite pronounced, and the CFL torchiere dramatically outperforms its halogen counterpart.

To understand how this difference in light distribution affects the actual illuminance in a room, the candlepower distributions from the halogen and CFL torchieres were placed in a Radiance computer model of a Stanford University dormitory room. Figure 6 shows the surface illumination (on floor, desk, chairs, etc.) in the model room for both the CFL torchiere (left) and the halogen (right). This model corresponds well with the distributional plots and shows the CFL torchiere matches the halogen close to the luminaire, but produces 15 to 20 percent more illumination further away from the fixture.

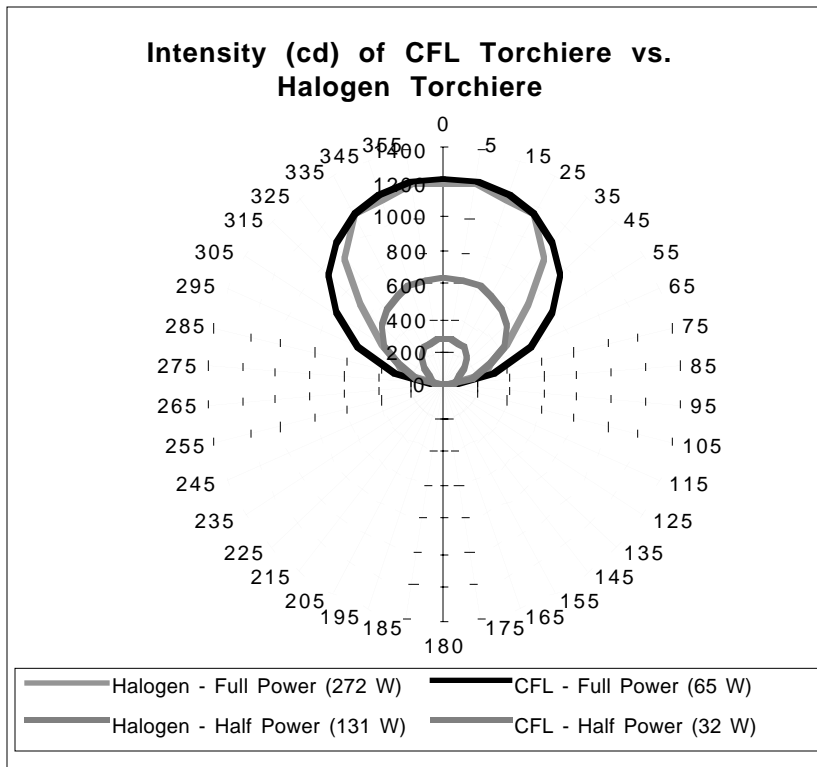


Figure 5: The Candlepower Distribution of a CFL Torchiere vs. a Halogen Torchiere

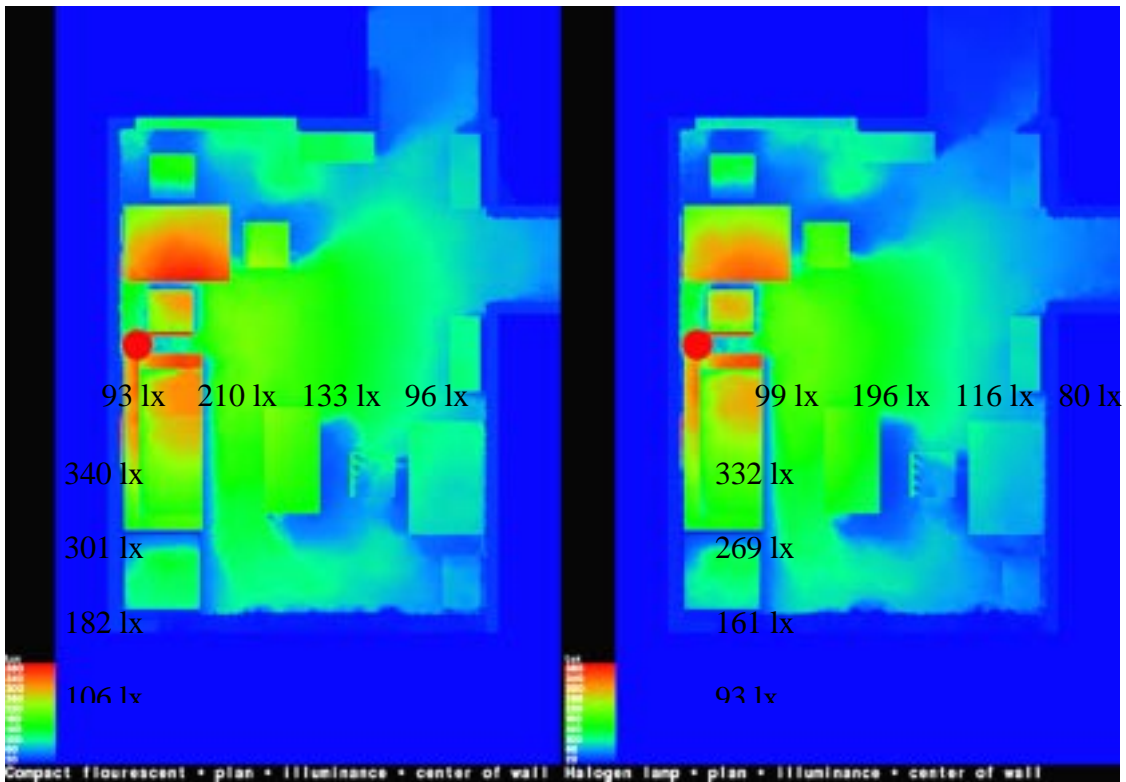


Figure 6: Radiance Computer Model of a Stanford Dormitory Room with a CFL Torchiere (left) and a Halogen Torchiere (right)

MARKET TRANSFORMATION ALLIES FROM THE INSURANCE INDUSTRY

The insurance industry is beginning to view energy efficiency as a previously untapped strategic opportunity (Mills and Rosenfeld, 1994; Mills 1996; Mills 1997), both because certain energy-efficiency technologies can prevent conventional insurance losses and because they can reduce emissions of greenhouse gases that some insurers believe are linked with increased rates of high-cost natural disasters (e.g. hurricanes).

Torchiere fixtures represent a prime example of an energy-using technology that is both responsible for conventional insurance losses (via house fires, health problems, and loss of life) and higher-than-necessary levels of greenhouse-gas emissions. Figure 7 graphically illustrates the massive heat produced by the halogen torchiere in an infra-red photograph of a 300 W halogen torchiere (left) next to the CFL torchiere (right). It is interesting to note that the CFL lamps' surfaces do not even reach temperatures as high as the wall directly behind the halogen torchiere.

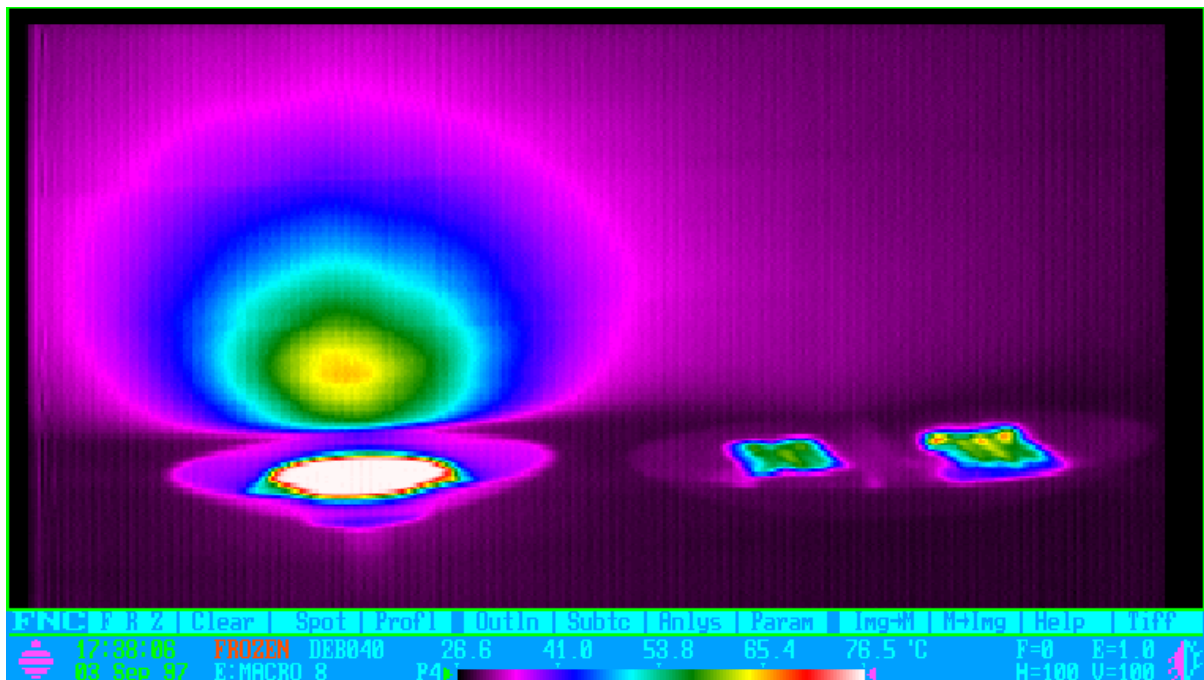


Figure 7: An Infra-Red Photograph of a Halogen Torchiere (left) and a CFL Torchiere

Individual insurers are now beginning to evaluate the merits of energy-efficient torchieres and prepare consumer-education materials directed at identifying safe and efficient alternatives. The Arkwright Mutual Insurance Company has issued a warning concerning torchieres that points out the additional energy benefits of shifting to safe units (Arkwright, 1997). In collaboration with Lawrence Berkeley National Laboratory, Arkwright subsequently initiated retrofits of halogen torchieres with CFL designs at Northeastern University and Tufts University, and are actively working to spread this practice to other universities around the United States. Other appropriate responses could include offering premium reductions for customers, such as universities, that ban torchieres (or premium increases for those who don't) or buying down the sircost of upgrading to an energy-efficient replacement fixture. Joint initiatives involving utilities and insurers are also being explored.

Insurers can also affect market transformation through information and rating programs. Underwriters Laboratories, which was founded by the US insurance industry early in the century and still serves that industry, has withdrawn their UL safety listing for certain torchiere fixtures and has established more stringent testing procedures. As an example of proactive rating and labeling, in the context of halogen fire hazards that can be eliminated by the use of energy-efficient torchiere designs, Arkwright Mutual has helped educate its customers about the EPA Energy Star labeling program for residential light fixtures.

SUMMARY

Staggering international market size and poor energy efficiency have combined to make halogen torchieres a major global energy gobbler. New energy efficient torchieres utilizing CFL technology are now entering the market that provide superior light output at a fraction of the energy consumption. Unlike halogen torchieres, these new torchieres operated at temperature well below that at which common household items (such as drapes) will ignite. Market transformation efforts have been initiated by energy conservation groups and the insurance industry to promote this efficient and safe luminaire.

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