Dimming of Compact Fluorescent Lamps Caused By Cold-Air Drafts

The Situation

The New York World Trade Center occupies a 16-acre site with its own postal code. Its 110-story twin towers offer about nine million square feet of rentable office space, making it one of the largest commercial customers served by the New York Power Authority (NYPA). In 1997, the Port Authority of New York and New Jersey (PA), which manages the Trade Center, decided to replace over 1700 incandescent lamps in the lobbies of the twin towers with energy-efficient, 32-watt compact fluorescent lamps (CFLs). As part of its High-Efficiency Lighting Program (HELP), NYPA financed and coordinated the installation of the CFLs, ballasts, and fixtures in the twin towers.

The canister fixtures—which accept T4, four-pin CFLs—were specifically designed for retrofit applications. The electronic ballasts that drive the lamps were mounted on steel beams that spanned the lobby. Figure 1 shows a sample CFL fixture, CFL, and electronic ballast removed from the Trade Center.

Shortly after the installation of the lighting systems, the PA reported complaints from some of the office renters about lights flickering in the lobby of one of the Center towers. Suspecting defective lamps and ballasts, NYPA asked the on-site contractor to replace the CFLs and ballasts in that tower. The removed ballasts and some of the lamps were sent to the fixture manufacturer for testing, while the rest of the lamps were sent to the lamp manufacturer. Meanwhile, the on-site contractor drilled a ventilation hole in each of the remaining new fixtures, suspecting that the lamps may have been overheating (see Figure 1).

Tests conducted by the fixture manufacturer confirmed that some of the lamps and ballasts were indeed defective. Although replacing the defective lamps and ballasts remedied the flicker problem, a new problem emerged: The CFLs now dimmed to about thirty percent of their normal illuminance during the night, especially as the outside temperature decreased. When the PA asked NYPA to determine the cause of the dimming, NYPA's Research and Technology Development Division initiated a power quality investigation.

Investigative Approach

First, NYPA monitored the lighting panel serving the CFLs that dimmed during the night and discovered that the voltage at the lighting panel was about 117 AC volts, well within voltage limits for lighting circuits. NYPA investigators installed a powerline monitor at the lighting panel for several days to record voltage, current, and harmonic distortion. Reviewing the data stored in the monitor, they discovered that a decrease in current at the CFL lighting panel coincided with the building's HVAC system turning on and off. As shown in Figure 2, the CFL produced normal illumination when the HVAC was turned on in the morning, drawing a current of about 40 amps. However, when the

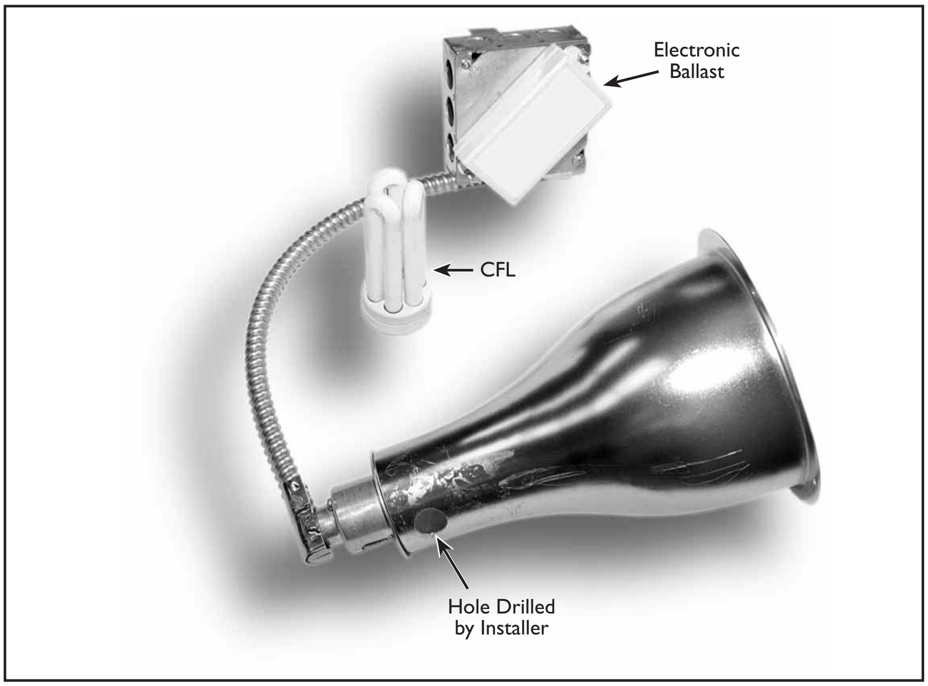

Figure 1. Lamp fixture, CFL, and electronic ballast removed from the New York World Trade Center

HVAC was turned off in the evening, the CFLs drew only about 35 amps of current, indicating low illumination.

Physically inspecting the CFLs, the PA and NYPA investigators noticed that the dimmed CFL fixtures were mounted in the plenum of the lobby, which carries return air from the HVAC system. While the HVAC is on, warm air flows through the plenum. When the HVAC is off, the airflow reverses, and the outside air is pulled into the plenum. The NYPA and PA investigators reasoned that because the dimming was worse during cold weather, somehow the airflow in the plenum must have been causing the problem.

To verify this theory, they pulled one of the recessed fixtures down. The light output of the CFL slowly recovered. When they replaced the fixture, the light output dimmed again. Suspecting defective CFLs, they replaced one with a lamp from a different manufacturer. However, it also dimmed about ten minutes after installation.

The investigators did not rule out radiated emissions, harmonics, inadequate grounding, and excessive neutral-to-ground voltages as possible sources of the problem. However, they were almost certain that the problem was environmental rather than electrical. The solution would be illusive without fully understanding the mechanism of the lamp dimming. In the busy lobby of the Trade Center, troubleshooting and experimentation is virtually impossible. Therefore, NYPA called on the EPRI Power Electronics Applications Center (PEAC) to help conduct laboratory testing to understand and solve the problem.

Laboratory Findings

To determine the mechanism causing the CFLs to dim, PEAC began to test the electronic ballasts, lamps, and their fixtures in an environmental chamber. At a University of Tennessee laboratory in Knoxville, sample lamps and ballasts taken from the lobby of the Trade Center were tested independently and as lamp/ballast units. All were found to be working properly, even when the environmental temperature was significantly reduced.

The effect of bulb temperature on the illuminance of a CFL is well documented. As shown in Figure 3, relative light output decreases (from the point of maximum

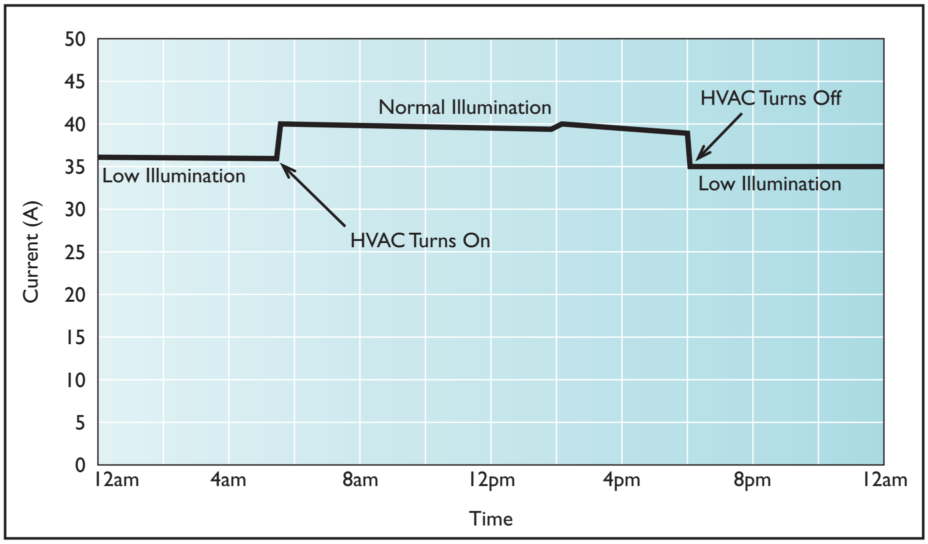

Figure 2. Current measured at a lighting panel during a 24-hour period

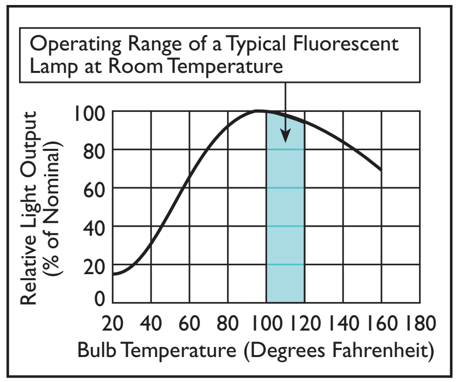

Figure 3. Relative light output of a typical fluorescent lamp based on bulb temperature (adapted from Barrow's *Light, Photometry, and Illuminating Engineering,* 1951)

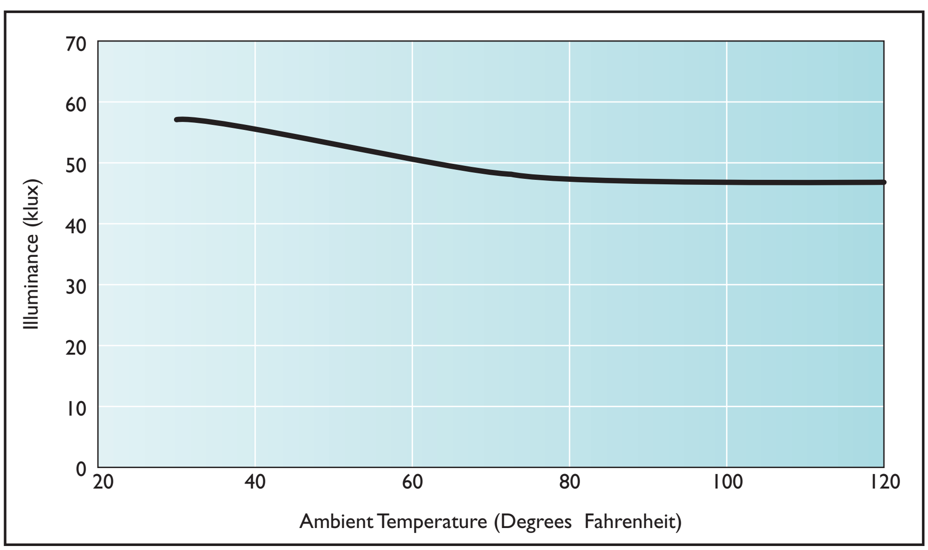

Figure 4. Illuminance of a tested CFL based on ambient temperature

light output) as the bulb temperature decreases. However, as shown in Figure 4, the ambient temperature had little effect on the illuminance of the CFL when the CFL was tested independently. In fact, as the temperature decreased from 120 to 30 degrees Fahrenheit (about 49 to –1.1 degrees Celsius), the illuminance increased. Changing the ambient temperature of the environmental chamber was simply not enough to significantly decrease the temperature of the CFL bulb. Therefore, the laboratory investigators suspected that the air flowing in the plenum was somehow cooling the CFL bulbs.

To simulate the cold airflows in the lobby plenum, a fixture containing a CFL was placed in a controlled environmental chamber and subjected to four airflow rates ranging from 0.83 to 4.95 cubic feet per minute (CFM), or about 0.024 to 0.14 cubic meters per minute. In one test condition, the drilled hole in the fixture was covered. For each test condition, the ambient temperature was reduced from 120 to 30 degrees Fahrenheit.

The results, shown in Figure 5, lend conclusive evidence that the cold airflow from the lobby plenum through the drilled ventilation holes and onto the lamps was causing the lamps to dim. The higher the rate of airflow through the hole in the fixture, the more the lamp dimmed. Figure 6 illustrates how the airflow affected the temperature of the CFL bulb much more than the ambient temperature alone (shown as “No Air Flow” in Figure 6).

Solution Verification

The research conducted at the University of Tennessee laboratory demonstrated that the holes in the CFL fixtures supplied a path for cold air to reach the CFLs, which are sensitive to direct cold airflow. To prevent this airflow, PEAC investigators

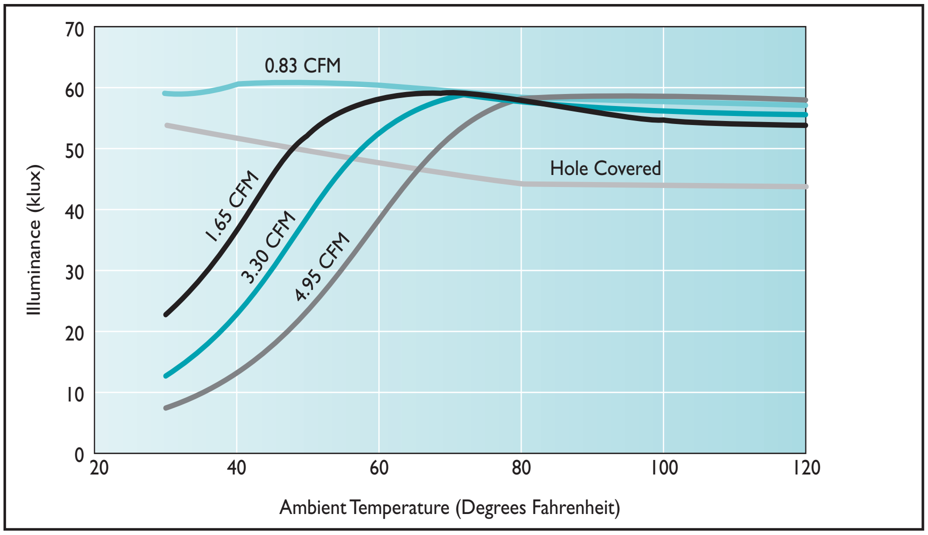

Figure 5. Illuminance of a tested CFL for different rates of airflow based on ambient temperature

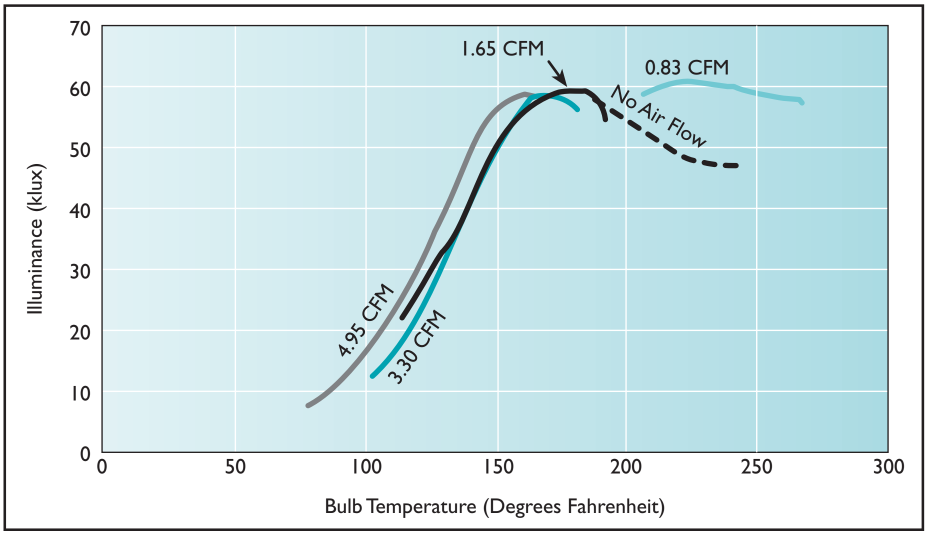

Figure 6. Illuminance of a tested CFL for different rates of airflow based on bulb temperature

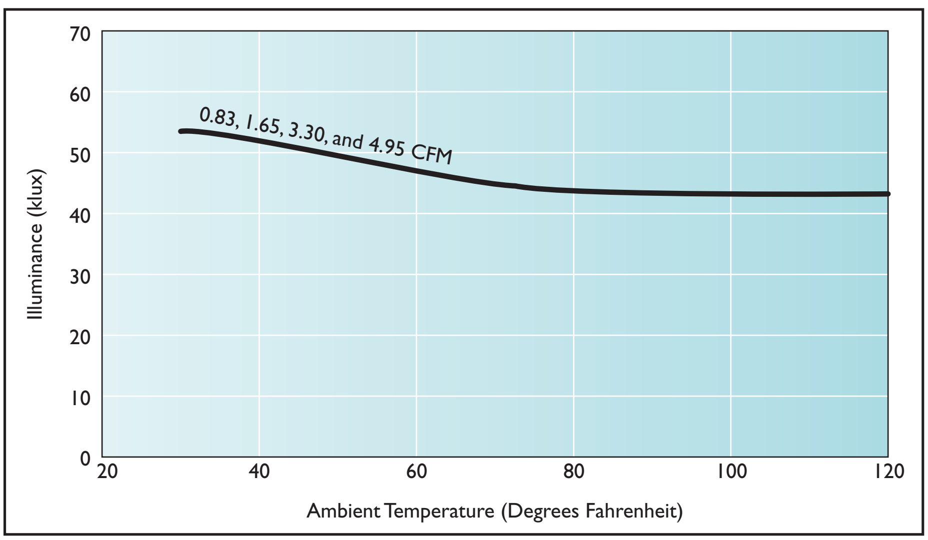

Figure 7. Illuminance of a tested CFL with the drilled hole covered for four different rates of airflow based on ambient temperature (identical results overlap)

covered the ventilation hole in the tested fixture. In the controlled environmental chamber, the solution was verified. Figure 7 shows the CFL illuminance at the four different rates of airflow. The illuminance-temperature curve is the same for all four rates, as indicated by the single line in the figure. Illuminance as a function of ambient temperature with the hole covered was similar to that shown in Figure 4, which shows the results of testing the CFL with the hole open and no airflow.

Figure 8. The solution: A neoprene gasket used to seal ventilation holes in the CFL fixtures

Conclusion

After the solution to the CFL dimming problem was verified in the laboratory, NYPA recommended that the on-site contractor seal the ventilation holes drilled in the CFL fixtures. Heeding NYPA's recommendation, the on-site contractor ordered high-temperature neoprene gaskets with adhesive backs and installed them over the fixture holes. One cold night in New York City verified the effectiveness of the gaskets and exonerated power quality as the culprit of the dimming problems. Figure 8 shows one of the gaskets used in the lobby of the Trade Center.

The diagnosis of the problem, development of a solution, and verification of the solution were all done in a laboratory, enabling NYPA to avoid disrupting the business of a very important customer. Combining field work with laboratory testing to troubleshoot power quality problems is often a very efficient approach, especially when the operations of the utility customer cannot be disrupted.

Key Terms: Compact Fluorescent Lamp, Reduced Light Output, Thermal Effects

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