

Designing with Dimming

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Wayne Morrow

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“We’re not in Kansas anymore Toto.”

Dorothy

Fluorescent dimming has come of age. Reasonable pricing, reliability, and control flexibility have made dimming a viable design option.

At the National Center for Atmospheric Research, NCAR, dimming design began in earnest six years ago. NCAR operates under the sponsorship of the National Science Foundation and is located on two campuses in Boulder, Colorado. We are governed by 62 member universities and pursue a mission to conduct and support research in the atmospheric sciences.

Much of our work centers around data collection and evaluation requiring supercomputing, networking, and personal computing facilities. Like many other organizations, our work has become increasingly computer intensive over the years and lighting performance had not kept pace. The poor quality and inflexibility of conventional T12, 60Hz, switched fluorescent lighting finally drove one of our divisions to develop their own ad hoc lighting system. Using dimming incandescents they were able to achieve the quality they needed but of course with the high heat output of incandescent lighting was making their rooms a little hot.

Our challenge was to create a system of equivalent performance but with fluorescent lighting efficiency. At this same time NCAR was undertaking a major renovation project to consolidate divisions at a new campus. Most of the space would be fixed wall perimeter offices designed for computer usage and computer grade lighting became a design objective.

Our first step was to move away from conventional T12 lamps to the newly available T8 lamps and electronic ballasts. Flicker and hum were eliminated by the electronic ballast and the whiter, almost full spectrum, light of the 4100K T8 lamps we selected improved vision clarity and focus (Sam Berman side bar on scotopic light). Motion sensors were added to reduce energy and individual dimming control was provided at each work station. and the system was integrated into our BAS to create an occupancy controlled working environment.

Occupancy control has helped us create a user oriented building where time clocks are used only for control of isolated tasks like hallways and parking lot lighting. Users may come in at any time and expect to receive full environmental services whenever they need to work. (see BAS interface side bar)

Performance

Single level lighting has never really worked very well. Multiple zones, dual switching, and specialty dimming have allowed us to limp by. However, just as the average family with 2.3 children does not exist, there is no average lighting user. Tasks change, equipment ages, and people vary. Lamp age and dust will reduce light output by 30% or more while user age, ambient daylight, individual physiology and personal preference all effect desired light output. Required lighting output is a moving target.

The best a lighting designer can do is to specify a range of light that covers the tasks and environment conditions. Discrete on/off control has provided users with limited capacity to adjust the light but dimming can provide a continuous range of light. This ability is especially important for computer lighting where even small changes in light levels can be important.

Color quality of lamps is measured on by a Color Rendering Index (CRI) number. Most conventional T-12 lamps have a rating of 56 while an incandescent is rated at 100. The index compares color quality with incandescent light. The high CRI T-8 lamps we are using have a rating of almost 90. With this lighting 30-40 fc is sufficient for most paper and meeting tasks, while computer users may desire ambient light levels as low 3-4 fc. Personal preferences vary widely so that some users never dim while others adjust light level throughout the day. Even so, in an independent survey conducted by the Lighting Research Center, 85% of occupants rated having a dimming system as important to very important.

Learning curves appear to be similar to other ergonomic elements. Users are often unaware of low-level stress. Poorly placed keyboards, bad seating, and lighting glare can be tolerated for extended periods. Over the long haul however, the price is repetitive stress injury. Carpel tunnel irritation, elbow and shoulder pain, and eye fatigue eventually make themselves known. Dimming at NCAR is seen as part of a comprehensive ergonomic program to assure that the workspace does impede productivity.

Personal Control

Dimming control at NCAR was initially provided only at the desk. On/off was automatic under the assumption that an occupied office should be a lit office. Lights automatically turned on and off depending on input from the motion sensor. Under this scenario door-side controls were not required or provided. The personal dimmer was a small ugly box with protruding knob intended to be mounted next to the computer. Daylighting control was also provided to maintain constant light levels as ambient daylight changed. Much of this control scenario is now being changed.

Automatic lighting control has an inherent big brother element. Work pioneered by Glass and Singer, (1972) **Urban stress**, established the importance of a personal "locus of control". A sense of personal control--even if not exercised--has a measurable and significant effect of performance while a loss of control as an opposite negative effect. These considerations were brought to our attention through numerous complaints about mysteriously changing light levels and the lack of manual controls. Automatic control was not generally viewed as convenience but more often as an intrusion and annoyance.

Several years after installation, an unfortunate opportunity presented itself in the form of a general failure of the dimming ballasts. This allowed required a redesign of the lighting control to fix several problems. Daylighting and auto-on was eliminated and a 3-way door-side control added. Poorly performing motion sensors were replaced and control logic was improved to eliminate false-on and off events.

Recently, the desk controller was also redesigned to be smaller and more attractive in order to facilitate placement at the immediate workspace. Users are being encouraged to consider lighting control as part of their computer workstation and to mount the controller on their monitor or keyboard where it can be accessed without reaching or searching. Microprocessor magic has also allowed this simple potentiometer device to provide on and off control to in order to allow users a convenient option to work with ambient daylight when available.

Reliability

Many initial experiences with electronic ballasts and dimming ballasts have not been favorable. A history of major product failures from many manufacturers suggests that caution is warranted. At our own facility the dimming ballasts begin failing shortly after installation. It was a disaster. Numerous fix attempts by the manufacturer were unsuccessful and eventually we and many other unwitting pioneers were left to fare for ourselves. It is an interesting note that dimming survived this period. Despite numerous proposals to eliminate dimming, the choice was made to fix it instead.

The fix-it program began with a search for a new ballast. Despite numerous performance specifications, the ballast industry does not provide reliability data. Defective products have routinely been sold along side quality products with little to go by except professional word-of-mouth.

NCAR maintenance personnel addressed this problem by developing a series of reliability tests starting with the famous Randy Archer paint shaker test. This is a simple test for loose and poorly mounted components. Ballasts are strapped in the shaker for few minutes while Randy has cup of coffee and then removed and tested.. Secondly, the ballast is tested for its ability to withstand a momentary power outage. This is the four-cycle outage test and is done by rapidly touching the power leads together. Randy also wrapped ballasts in insulation to test for overheating response and ran them with missing lamps.

During the course of these tests potting was observed to ooze out of some devices and components sheared off of others. One brand could not pass the short-cycle outage test and would shut off each time it saw a power bump. Other units failed right out of the box. We then followed up these tests with 6 months of field tests.

NCAR now has over 2 years of history with our replacement dimming ballast and we have installed well over 1000 units. Failures have been negligible, Randy has been reassigned the paint shaker is again being used to mix paint.

NCAR is not a testing lab and our tests where much too ad hoc to publish. However we were able to prove to ourselves that performance testing is possible and our maintenance department

finally bought off on the ballast we are presently using. We have also communicated our experience to the Lighting Research Center and suggest that the ballast industry would do well to initiate such testing guidelines themselves instead of using customers as unknowing beta sites.

Costs

Not surprisingly, dimming is more expensive than conventional fluorescent lighting. The ballasts we are using cost about twice as much as an equivalent non-dimming product. Controls and installation are also more expensive. For new construction a 2 lamp dimming system is about cost equivalent with a 3 lamp dual switching system. Addition of the desk-side personal control adds another \$100-150 depending on installation difficulty.

The most economical use of dimming is as a replacement for indirect lighting. Where ceiling height is limited or where cost is an issue, a 2 lamp direct dimming fixture with good specular louvers can be an effective alternative. Fixture cost and energy use is reduced by about 50% and some interesting control options become possible (see applications section below).

Dimming can also be an effective retrofit. Refurbishing a 4 lamp T12 system or a 3 lamp parabolic fixture to a 2 lamp T8 dimming system with a white reflector and personal controls is costing us about \$400 per office installed. These additional costs do extend the direct payback another 4-5 years but with the substantial benefit of a greatly improved lighting system. Dimming does achieve additional energy savings but independent tests conducted by the Lighting Research Center at our Boulder facility show that this savings is only about 1/2 of energy savings achieved through use of a motion sensor.

These ballpark numbers suggest that dimming is not a cost effect as an energy saving strategy. Rather, dimming needs to be evaluated as part of a strategic ergonomics program. A personal dimming system costs less than an articulating keyboard support and has similar benefits. The goal of computer lighting is to achieve a low uniform level of illumination within the work space. Good overhead lights with dimming can do this much more effectively than task lights.

Controls

If the dimming ballast is the heart of a dimming system then controls are certainly the brains. Fluorescent dimming happens in the ballast. Controls act indirectly by telling the ballast what to do. On/off control is still provided in conventional way through a switch or relay. The type of control used depends on the communications protocol of the ballast. The dimming message can be communicated to the ballast with class 2 or power wiring using either digital or analog protocols. The choice of protocol will effect cost and flexibility of the system. Proprietary protocols have the standard problem of being proprietary--controls are available only from a single provider. Open protocols like 0-10v allow an open market competition so selection, pricing, and availability tend to be better.

The most control device is the wall mounted slide dimmer with manual on/off switch. This device works well for simple dimming applications. However, adding motion sensors, 3-way control, and a BAS interface complicates the picture rapidly and a systems approach becomes necessary. The NCAR controller was developed to act as a system integrator. The controller provides a hub

where all peripheral elements are connected and their interaction coordinated. This concept has improved performance while also simplifying installation and maintenance.

Applications

Most lighting applications benefit from the greater flexibility and improved control available with dimming. Unlike conventional switch zones, dimming zones—at least with the 0-10v dimming system we are using—are independent of power distribution. Even if lights are on different power circuits they can be dimmed as one zone or broken into smaller or larger dimming zones.

Dimmer control can be as simple as a low wattage potentiometer or as comprehensive as the microprocessor based integrated system we are using. For most designers the entry level control will be one of the commercially available wall dimmers. These devices mount in single gang box and provide simple single station dimming control. Capturing dimming's true potential however requires more flexible devices.

Typical applications:

- a) Small public rooms and offices without computers or motion sensors - A conventional single station wall dimmer is very effective for this limited application.
- b) Fixed wall offices - Very effective - These type of offices are inherently dedicated personal environments. Providing task related quality lighting and full personal control makes sense. We use deep cell fixtures, a ceiling mounted motion sensor, and 3-way dimming controls placed at the door and the workspace. The low voltage personal control plugs into an RJ11 jack which is installed separately or in conjunction with the communications system.
- c) Conference rooms - Dimming is perfect for presentations. Users are typically asking for two control zones with a one zone provided for the fixtures immediately adjacent to the presentation area. For basic installations, 3-way wall controllers are mounted at both the front and rear of the room. For multimedia rooms, the controls are integrated into the room control panel.
- d) Labs - Dimming is generally a good idea as it allows the researcher to choose appropriate light levels for the task being performed. Many labs are increasing computer intensive and we are treating smaller labs like an office so a personal controller can be installed at a computerized test or development station. Larger labs with two entrances receive on wall controllers at each door and specialized dimming zones can be created as necessary.
- e) Open-plan offices - These spaces have traditionally been designed with homogeneous ambient lighting often using indirect fixtures. Dimming offers some alternatives. First it is possible to dim the indirects providing an allowance for lumen depreciation and providing for very low ambient levels where necessary. Secondly, where headroom or cost is an issue, dimming can make direct lighting an effective alternative to indirect. A third application is the one I find most interesting. A major problem with open space offices is the loss of privacy. Homogenous lighting can economically privatized by using personal controllers in conjunction with low incident angle fixtures arranged over workspaces..

Conclusion

After decades of enticing promise and wide-spread product failures, fluorescent dimming has finally become a realistic and effective design option.

Sidebar

The BAS Interface

Occupancy control of working space has created some surprising and unanticipated benefits in comfort and capital equipment savings. NCAR offices are primarily fixed wall with individual cooling and shared heating. Originally, the concept of occupancy management was conceived of as an energy saving feature. Motion sensors were installed for HVAC control and the data shared with the lighting system to amortize costs over a larger base of services.

Lights in unoccupied areas are first dimmed and then turned off during unoccupied periods while temperature settings are set back and minimum air flow eliminated.

Concerns about maintaining constant temperatures in unoccupied rooms provided unfounded. Thermal mass has been sufficient to maintain acceptable limits and an early morning purge prepares the building for occupancy. The unanticipated benefit is that rooms stay warmer.

VAV systems are designed to do double duty. They supply fresh air and cooling. Conventional design requires that minimum air flows be maintained. During the summer and within the core of the building heating is typically not provided. Constant cooling results in some very cold working spaces. Temperature in one interior conference room was routinely dropping into the low 60's over the weekend. Time clocks could address this problem but what about evening and weekend meetings? Offices with little sun exposure were having the same problem so that even in summer rooms were getting too cold.

The second related problem with VAV systems that heating and cooling systems are at odds with each other. Where heat is available, air flow and heating must constantly modulate in an attempt to maintain the setpoint temperature. Reheat coils can help but tolerances and control latencies will still assure a constant dual as both systems seek an elusive equilibrium.

This kind of hyperactivity and energy use may be acceptable in an occupied space but certainly not in an unoccupied space. NCAR's occupancy rate at any time can be as low as 40% during the workweek and is seldom higher than the often quoted average of 60%. Over nights and weekends occupancy can be close to 0%.

Before turning on our HVAC occupancy control we trended these competing systems. After switch-over the effect was dramatic. Equipment operation was reduced by about two thirds and more importantly, cold room syndrome was eliminated while HVAC resources are being more effectively allocated to occupied space with the result that services can be maintained even on the hottest days.