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PHOTOELECTRIC CONTROL OF EQUI-ILLUMINATION LIGHTING SYSTEMS

Francis Rubinstein

SUMMARY: The ability of a photoelectrically controlled lighting system to maintain a constant light level on a task surface by responding to changing daylight levels is affected by the control algorithm used to relate the photosensor signal to electric light levels and by the geometry and location of the photosensor. We describe the major components of a typical equi-illumination system, discuss the design and operation of such a system, and examine the effects of the control algorithm and photosensor shielding.

The following is from a discussion with Francis Rubinstein:

ASD: What is an equi-illumination lighting system?

Francis: An equi-illumination lighting system is a system which maintains a relatively constant level of light at the work surfaces in a daylit space as a function of time of day. Obviously, in any brightly daylit room this is not achievable in an absolute sense since daylight alone will often exceed the design level within a space.

ASD: Why is achieving a relatively constant level of illuminance throughout the building space such an important and difficult problem?

Francis: The problem arises because in any real building you have to place the control photosensor -- the detector which measures the amount of light in a space -- in the ceiling or some location that is remote from the work plane where we are concerned with the design light level. The reason for placing the photosensor, for instance, in the ceiling rather than on the desk is to minimize the possibility of the occupant accidentally affecting the operation of the system and to simplify its wiring into the electrical and control systems.

Unfortunately, locating the photosensor in the ceiling makes it considerably more difficult to maintain a constant light along the work plane, precisely because the sensor is no longer in the proper place. It's a little like designing a cruise control system for a car without a means to detect the vehicle's speed.

ASD: In the paper you say that the ability of the photoelectrically controlled lighting system to maintain a constant light level on a task surface is affected by the control algorithm used to relate the photosensor signal to electric light levels. I am not sure that I understand what this means; could you explain?

Francis: The control algorithm is basically the relationship between light as detected by the sensor and the output of the electric lighting system. It is also sometimes referred to as a transfer function. The actual choice of control algorithm is a circuit design consideration and manufacturers are free to use any algorithm that they choose to design. Most of the presently available systems use an algorithm that raises or lowers the electric light level so that the output of the sensor is held constant. In other words, these systems work by maintaining a constant amount of light on the sensor in the ceiling. However, maintaining a constant amount of light on the ceiling is not the same thing as maintaining a constant amount of light on the work plane. In fact, one often finds an ironic situation: the more daylight that enters the room, the lower the total light levels actually are.

ASD: You also mentioned that equations for the control photosensor signal are developed that separate the signal into electric light and daylight components. I would think that this is a very difficult thing to do. Perhaps you could elaborate on it?

Francis: Well, you're right, it is a fairly difficult thing to do physically, with a circuit. I do it mathematically in the paper to clarify the concept that daylight is the stimulus (on the control system) while the resultant electric light level is the response.

ASD: What is the most important finding in this paper, and what do you estimate still needs to be done in this area?

Francis: The most important finding was that a properly designed daylight-dimming system should allow the end-user to adjust, on-site, the degree to which the electric lights will dim in response to a given change in light on the photosensor. By allowing the user to change the effective gain of the system in this manner, one can provide reasonably constant light levels at the work plane regardless of the particular daylight level or room geometry.

There are several areas in which we feel more work needs to be done. So far we have looked at the relationship between light as detected by a sensor and illumination on the work plane in a simple model of a small office. It is clearly important to look at these relationships in other kinds of building spaces and to examine how various shading devices affect these relationships. We are preparing to begin such research next year.

ASD: How do you deal with the problem that most animals, humans included, undergo circadian rhythms that are related to changing light intensity throughout the day? I would suspect that the situation in which the light intensity is perfectly uniform throughout an 8-hour period may not be very comfortable for humans. Are you in any way trying to address these issues?

Francis: It is certainly true that the human species has evolved under conditions where the light levels vary drastically over the day. Whether or not this is beneficial from the point of view of human physiology and comfort is being argued within the lighting community today. However, one has to realize that in any real daylit space, it is impossible to maintain a perfectly constant light level throughout the day because of the large dynamic variability of daylight. The purpose of the lighting controls should not be to eliminate all this variability, but rather to assure that sufficient electric lighting is supplied when daylight is insufficient to meet the needs of comfort and productivity. The problem that I see with current systems is not so much that they do not maintain an absolutely contant level of light throughout the day, but rather that they tend to allow total light levels to drop significantly below the design level during the day. It is this tendency of the systems to undersupply the necessary light that is of major concern. During the day, the exterior environment is often extremely brightly lit, which tends to lead to the perception of glare and discomfort. In fact, in the United Kingdom, lighting design practices have taken this explicitly into account. If a lighting system is designed to provide 50 ft.-candles at night when the exterior is dark, then the system would be designed to provide perhaps 75 ft.-candles during the day when there is a bright external reference point. With an adjustable gain system, such schemes are easily achievable by proper calibration of the system response.

HONORS

In *Ashrae Fundamentals, 1985,* the ASHRAE Handbook Committee acknowledged, in addition to the Technical Committees, individuals who contributed significantly to their latest volume. **Helmut Feustel, Dave Grimsrud, Dariush Arasteh, and Steve Selkowitz** were listed from LBL.

PATENTS GRANTED

Dick Fish was issued U.S. Patent No. 4,518,490 for the process for Removal of Arsenic Compounds from Petroliferous Liquids.

VISITING RESEARCHER

From July until the end of September of this year, Enno Abel is visiting the Energy Efficient Buildings program on sabbatical leave from Chalmers University of Technology, Gothenburg, Sweden. At Chalmers, Professor Abel is Head of the Department of Building Services Engineering. His main area of concentration is on building energy (HVAC) systems.

Born in Tallinn, Estonia, Abel took his advanced degree in Mechanical Engineering at the Royal Institute of Technology in Sweden. After graduation, he spent two years working for the Atomic Energy Company in that country, where he was involved in the planning of the first atomic reactors there. During the following decade, he worked as an energy consultant with a government-owned firm engaged in the design of nonresidential buildings. He currently serves on the Board of Directors of the Swedish State Power Board and is a member of the Royal Academy of Engineering Sciences.

During his sabbatical, Professor Abel has been studying the supply and use of electricity and heat in buildings in the United States, having visited plants in New York, Minnesota and Southern California. He has a strong interest in cost-effectiveness, since he believes that in the long run, cost efficiency is the primary determinant of the viability of energy systems in buildings. He has been particularly impressed by the enthusiasm and overall perspective of the EEB program researchers, whose emphases, in his view, are on "finding the essentials" and the economics of systems.

WHERE DO YOU STAY IN WASHINGTON, D.C. WHEN YOU CAN'T AFFORD $175/NIGHT AT THE WESTIN HOTEL?

According to information from members of our Energy Efficient Buildings Program, you could try the following reasonable alternatives:

(1) Holiday Inn - Capitol [Tel. (202) 479-4000]; located one block from DOE's Forrestal Building. Price: $58/night for a single room (government rate). They fill up fast so you need to make reservations early.

(2) Harry Misuriello's Studio/Apartment, 537 - 5th Street, S.E.

The studio is located in the basement of Harry's apartment and has a full kitchen, t.v., private bath, linens, towels, fold-out queen size couch for bed, separate entrance. The studio is located approximately 10 blocks from the Forrestal Building, 8 blocks from the Capitol, and 2 blocks from the Metro (Eastern Market).

Price: $35/night* (negotiable for long stays)

To make reservation call:

Home: (202) 543-7408 Work: (202) 543-7212

Ask for Harry and tell him "Art sent you!"

(*as of '84)

INDOOR AIR QUALITY AND HUMAN HEALTH

by Isaac Turiel

Indoor Air Quality and Human Health, recently published by Stanford University Press, was written by **Isaac Turiel** of the Energy Analysis Program. The book is reviewed in the July 1985 issue of Scientific American, and is described as "a model of balanced simplification of a complicated and embattled topic." Turiel's book discusses indoor air pollutants in residential and office buildings, their health effects, and methods of pollutant control. The book deals in large part with the possible tradeoff between energy efficiency and health risks. Our modern buildings contain a wide variety of combustion appliances and substances whose emissions and degradation products can contaminate the air. They include cigarette smoke, pesticides, organic sprays and solvents, radon from the subsoil, and foam insulation. Foam insulation (urea-formaldehyde resin) provides a salient example of a health risk associated with a means of energy efficiency, in that it releases a formaldehyde vapor that even in relatively low concentrations can induce respiratory illness in a significant fraction of people exposed to it.

Scientific American commends *Indoor Air Quality and Human Health,* which, it concludes, "...is a factual, nontechnical and even-handed book that is a fine place to encounter at a simple level the methods of and the quandaries around public health in a complex and changing society."

RECENT REFEREED JOURNAL ARTICLES

I.V. Fry, G.A. Peschek, M. Huflejt and L. Packer, "EPR Signals of Redox Active Copper in EDTA Washed Membranes of the Cyanobacterium Synechococcus 6311," *Biochemical and Biophysical Research Communications, 129* No.1, pp. 109-116 (1985).

C.F. Edwards, H.E. Stewart and A.K. Oppenheim, "A Photographic Study of Plasma Ignition Systems," *SAE Technical Paper Series 850077,* pp. 1-10 (1985).

M.L. Warren and M. Wahlig, "Cost and Performance Goals for Commercial Active Solar Absorption Cooling Systems," *Journal of Solar Energy Engineering, 107,* pp. 136-140 (1985).

F.C. Winkelmann and M. Lokmanhekim, "Sun-control Options in a High-Rise Office Building," *Energy and Buildings, 8,* pp. 1-13 (1985).

M.C. Ball, R.J. Mehlhorn, N. Terry and L. Packer, "Electron Spin Resonance Studies of Ionic Permeability Properties of Thylakoid Membranes of *Beta vulgaris* and *Avicennia germinans,*" *Plant Physiol., 78,* pp. 1-3 (1985).

H. Dersch, A. Skumanich and N.M. Amer, "Influence of Dangling-bond Defects on Recombination in *a*-Si:H," *Physical Review B, 31* No. 10, pp. 6913-6916 (1985).

O. Rashed and N.J. Brown, "A Molecular Dynamics Study of the Reaction $H_2 + OH \rightarrow H_2O + H$," *J. Chem. Phys., 82,* No. 12, pp. 5506-5518 (1985).

INVITED TALKS AND FOREIGN TRAVEL

June

- Arlon Hunt attended the International Solar Energy Society's Intersol 85 Conference in Montreal, Canada. There he delivered papers entitled "Direct Radiant Heating of Particle Suspensions for the Production of Fuels and Chemicals using Concentrated Sunlight," and "Aerogels, a Transparent Insulator for Solar Applications." He also chaired a session on "High-Temperature Concentrating Collectors."

- Joe Klems was the U.S. representative at a meeting of the International Energy Agency (IEA) Annex XII -- Windows and Fenestration -- in Delft, The Netherlands.

- Art Rosenfeld (and John Holdren, Prof. of Energy and Resources) were part of a 10-person team of U.S. academics and engineers from Berkeley, Michigan, MIT, Princeton, and Univ. of Texas - Austin, invited by the Soviet Academy of Sciences to discuss a new Soviet conservation policy.

July

- Tica Novakov was an invited reviewer at a DOE Review meeting at the Oak Ridge National Laboratory in Tennessee. The subject of the review was "The Effect of Acid Rain on Materials."

- Olivier de la Moriniere and Art Rosenfeld travelled to Paris to participate in a series of press conferences and interviews where they discussed California's energy conservation programs.

August

- Lee Schipper traveled to Frankfurt, Duisburg and Hamburg, Germany; to Eindhoven and The Hague in Holland; and to Stockholm, Sweden; Oslo, Norway; Copenhagen, Denmark; and London, England. The purpose of his trip was to discuss energy data and appliances with various corporations and governmental organizations.

LBL WEDDING BELLS!

Ed Vine, a staff scientist in the Energy Analysis Program, and *Ellen Singer*, a psychologist who works at Kaiser Hospital, were married on Sunday, September 1, in the Faculty Glade on the U.C. Berkeley Campus.

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