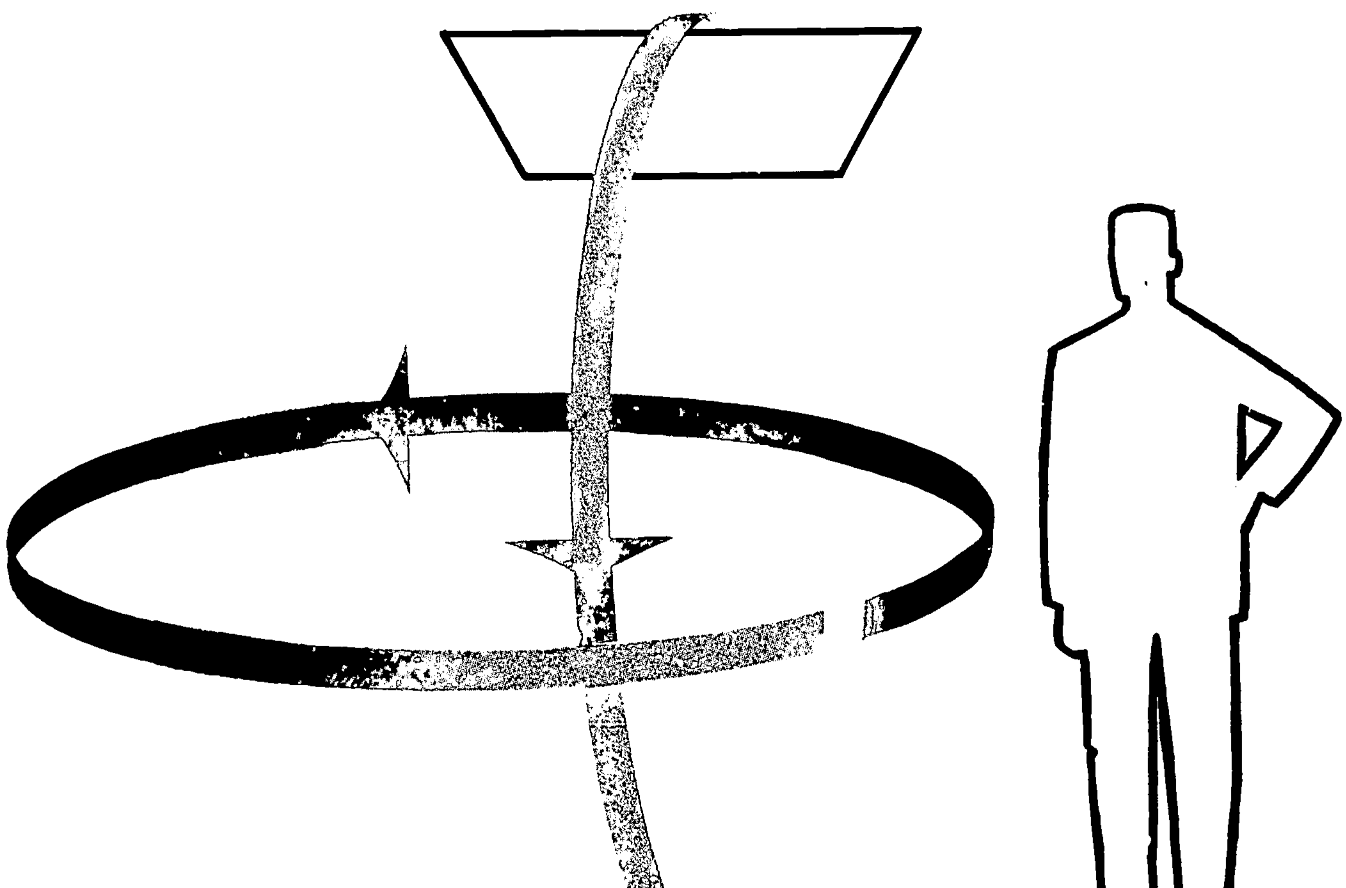
DOCUMENT RESUME

ED 026 825 EF 002 513

Electrical Space Conditioning.
General Electric Co., Cleveland, Ohio. Large Lamp Dept.
Report No-TP-126
Pub Date Mar 66
Note-24p.
EDRS Price MF-$0.25 HC-$1.30
Descriptors-Air Conditioning, *Building Design, *Building Equipment, Building Operation, Climate Control, *Design Needs, Electrical Systems, *Heating, Illumination Levels, *Lighting, Lights, Solar Radiation, Specifications, Thermal Environment

Integrated systems utilizing the heating potential of lighting equipment are discussed in terms of the implications for design and the methods for evaluation and control. General principles cover heat transfer, heat from lamps and luminaires, and control of lighting heat. Suggested systems include--(1) total control systems, (2) bleed-off systems, (3) separate systems, and (4) water and air systems. All electric system components such as heat pumps and electric supplementary heating are also described. Extensive use is made of illustrative photos, schematic drawings, and charts showing heat and light outputs of different lamps, and heat transfer with different exhaust methods. (MM)

electrical SPACE CONDITIONING



TP-126
LARGE LAMP DEPARTMENT
GENERAL ELECTRIC

PUBLISHED BY GENERAL ELECTRIC COMPANY/LARGE LAMP DEPARTMENT/NELA PARK/CLEVELAND, OHIO

Lighting is an integral part of the heating and cooling system in this modern electrical-space-conditioned building. Three-lamp luminaires mounted between structural floor beams produce more than 200 footcandles of illumination. Parabolic wedge louvers present low ceiling brightness and allow return air to be drawn up past the lamps and out the top of each fixture.

ELECTRICAL SPACE CONDITIONING

■ Electrical space conditioning combines the best efforts of the architect and engineer in coordinating lighting, heating, and cooling systems to create the best possible environment within a building. Electrical space conditioning may also include control of dirt, bacteria, ions, and odors in the building atmosphere.

Proper lighting is of paramount importance in creating a pleasant environment that promotes the highest working efficiency. Human visual performance is stepped up through improved task visibility. Worker attitudes and motivation are stimulated. Frequently, lighting is designed for the sole purpose of enhancing an atmosphere or highlighting the furnishings in a given environment. Lighting is also used extensively at night as an effective advertising medium. Energy loads resulting from such diverse uses of lighting have quite an effect on the thermal conditions within buildings.

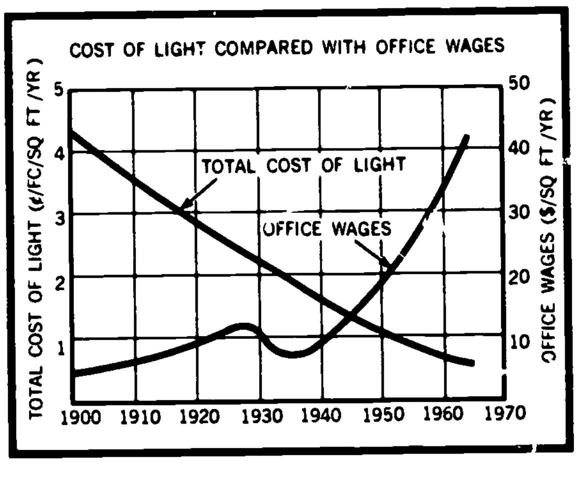
Current recommendations for lighting quantity, although higher than in the past, are low compared with the values desirable for best visual performance. The optimum lighting levels for offices, schools, and many commercial establishments are about 500 footcandles. For some industrial areas, 1000 or more footcandles may be required. Continued research will improve electric lamp efficiency and reduce the cost of power generation. These efforts will make it increasingly practical and economical to provide the quantities of illumination needed for highest visual performance.

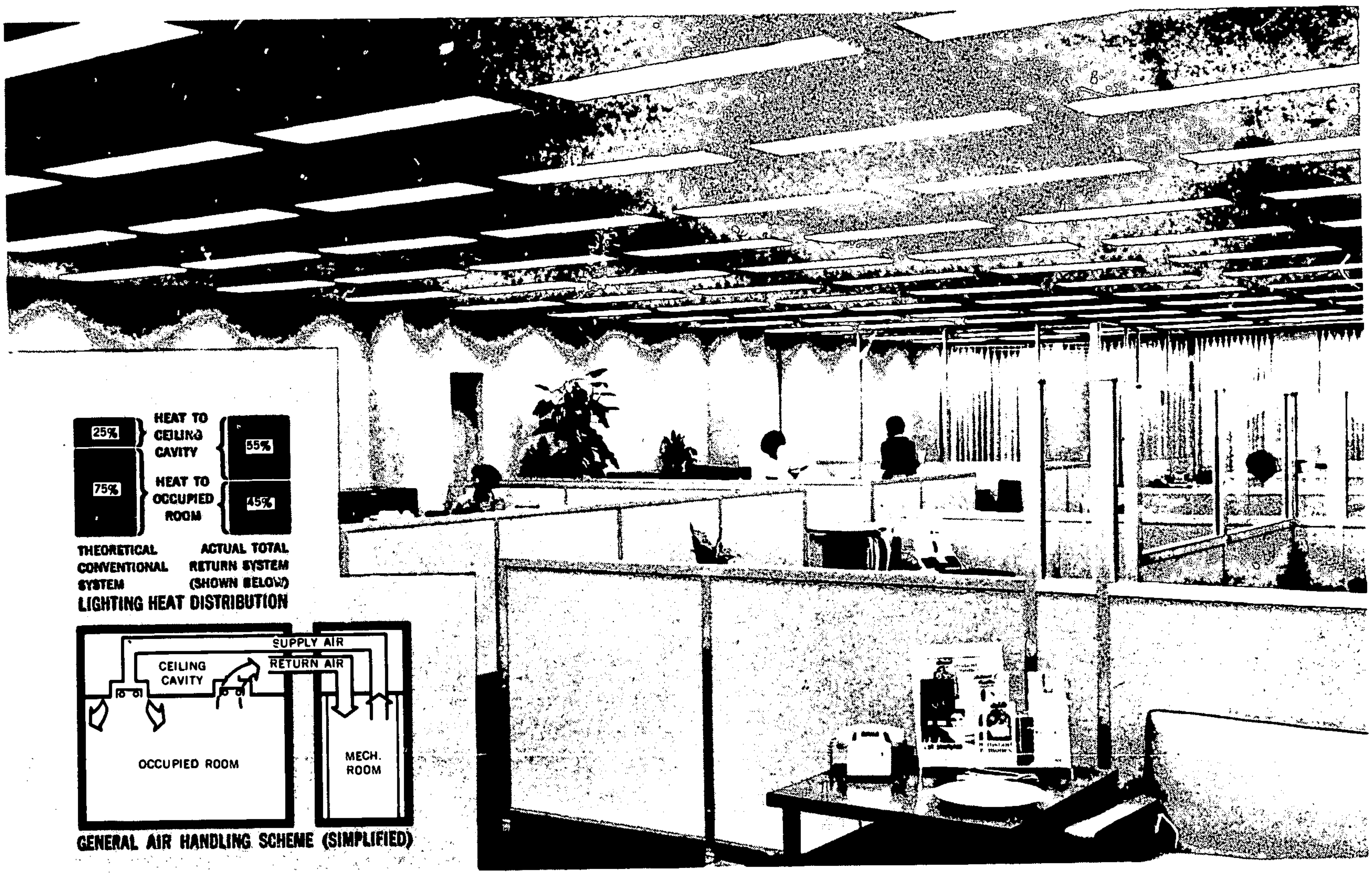
The expanded use of lighting heralds a new era in environmental design. It provides the opportunity to supply all, or a substantial part, of a building's heat losses with lighting. There are also possibilities for handling lighting heat more efficiently during warm weather. However, since a building's heating requirements change from hour to hour and parts of a building have different needs at a given moment, control of lighting heat is necessary for most effective utilization. Fortunately, much of the heat can be controlled.

The primary reason for installing lighting is to serve visual requirements. However, when the desired lighting also has the capability for providing heating, it should be coordinated with the thermal design.

Electrical space conditioning also heralds the beginning of the all-electric era in commercial and industrial buildings. When lighting is integrated with thermal design, the economics of electric heat fo: providing any supplementary requirements are enhanced. Already electric energy rates in many parts of the country make ESC systems competitive with fuel-fired heating. If the well-defined trends in electric power cost and fossil fuel cost are projected over the expected 40-year life of a building, an all-electr:c building designed according to ESC principles offers the best value.

Over the years, lighting has become a better and better buy in relation to wages, building costs and other business expenses. In the United States in 1900, 1 footcandle of illumination cost about 7% of an average worker's wage. Today, 200 footcandles cost abcut 3.5% of wages.





Interior of first high-rise office building using heat-transfer troffers throughout for controlling lighting heat. Two 40-watt lamps in each luminaire produce about 125 footcandles of illumination. About one-third of the luminaires supply input air at the sides of the unit; all luminaires return air through the lamp compartment. In this system, only 45% of the lighting heat enters the rooms thereby reducing the volume of air necessary to handle heat gains in the occupied space. Blower horsepower and friction losses in the ducts are reduced, saving on operating cost. The fluorescent lamps also produce about 10% more light because of more favorable operating temperature in the luminaires. The extra light provided is worth about $10,000 per year in terms of lamps, fixtures, power, etc., that would have been required if the heat-transfer luminaire system had not been used.

GENERAL PRINCIPLES

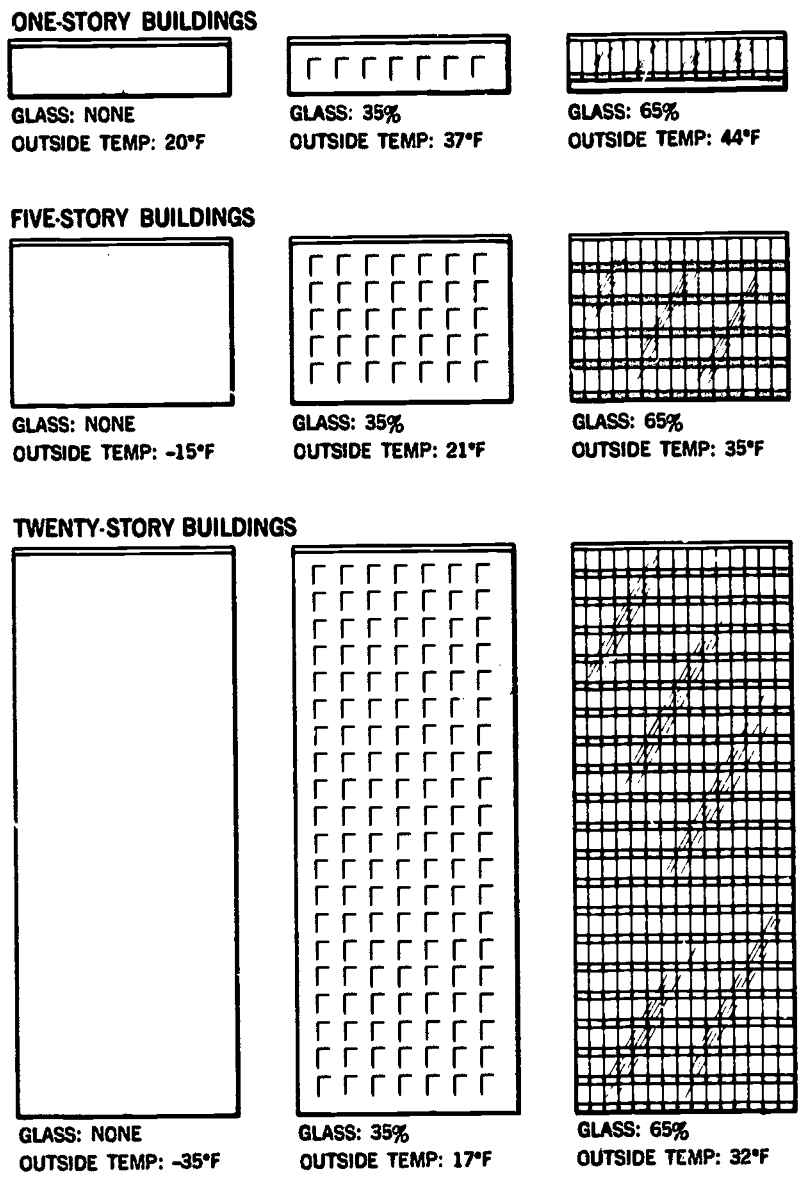
Current lighting practice has altered the economic parameters for lighting, heating and cooling. Lighting is not considered an independent factor in building design in view of its influence on thermal design. Newer concepts of system integration now offer better comfort, improved performance, and lower costs in some of today's buildings.

The products and systems which make buildings more efficient and desirable today also introduce energy into the environment. Some typical examples, in addition to lighting and heating units, are computers and other business machines in offices, electric motors for refrigerated cases in supermarkets and for production equipment in industry. People themselves produce substantial heat energy which goes into the environment. Further, when the solar load imposed by some types of building designs is added to the other internal energy, it may tax the capability of conventional air systems to handle all the heat gains in a space.

New techniques and equipments now available for controlling lighting heat make it possible to pick up a substantial portion of this energy before it enters the occupied space. Depending on the type of system, the captured heat may be recirculated where needed, transferred by means of heat exchangers, mixed with outside air in various proportions or, in some cases, exhausted to the outside, whichever is more economical.

At night, if it is not necessary to operate the

LIGHTING HEAT AND BUILDING DESIGN



With 6 watts/sq ft of lighting installed in all buildings above, the lighting heat gains equal the building heat losses at the outside temperature indicated for each building. This means, for example, that the 20-story, 35% glass building needs no supplementary heating until the outside temperature drops to 17°F.

Functional and Economic Advantages of Electrical Space Conditioning

1. Improved thermal comfort due to lower air volumes and luminaire temperatures.

2. Smaller supply duct sizes and lower blower horsepower, reducing head room requirements and both initial and operating costs for air handling.

3. More usable or rentable space with an all-electric design.

4. Increased light output from fluorescent lamps because of more favorable operating temperatures.

5. Enhanced performance of fluorescent lamp ballasts due to lower ambient temperatures.

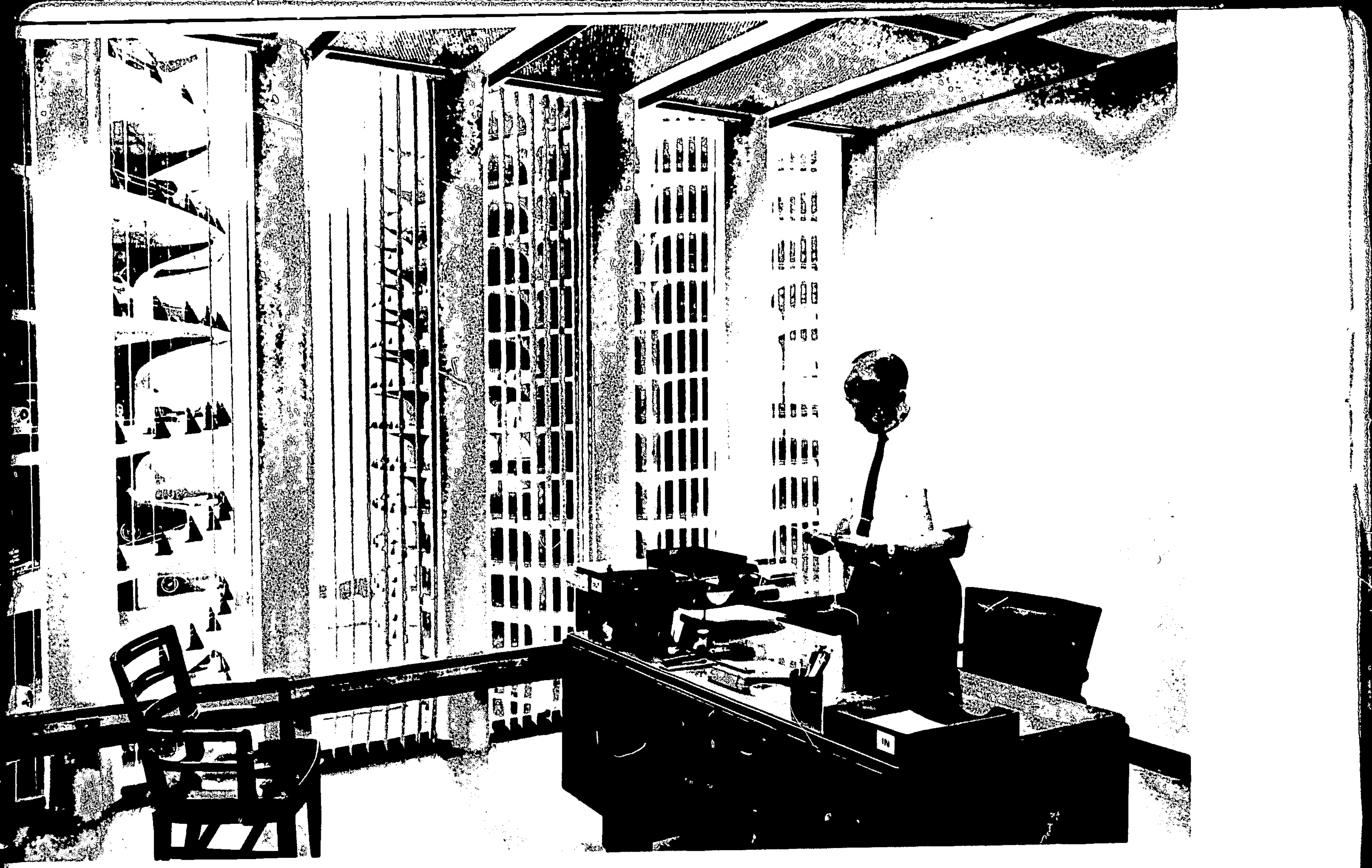
6. Reduced demands for conventional heating if lighting supplies a significant part of building heat losses.

7. Better economics for electric heat and all-electric building systems.

8. Reduced requirements for mechanical room space with an all-electric design.

9. Elimination of a chimney with an all-electric design.

10. Reduced air conditioning tonnage if requirements for ventilation air are sufficiently great so that this ventilation air can be exhausted through the lighting fixtures. (Climatic conditions and ventilation requirements govern applicability.)

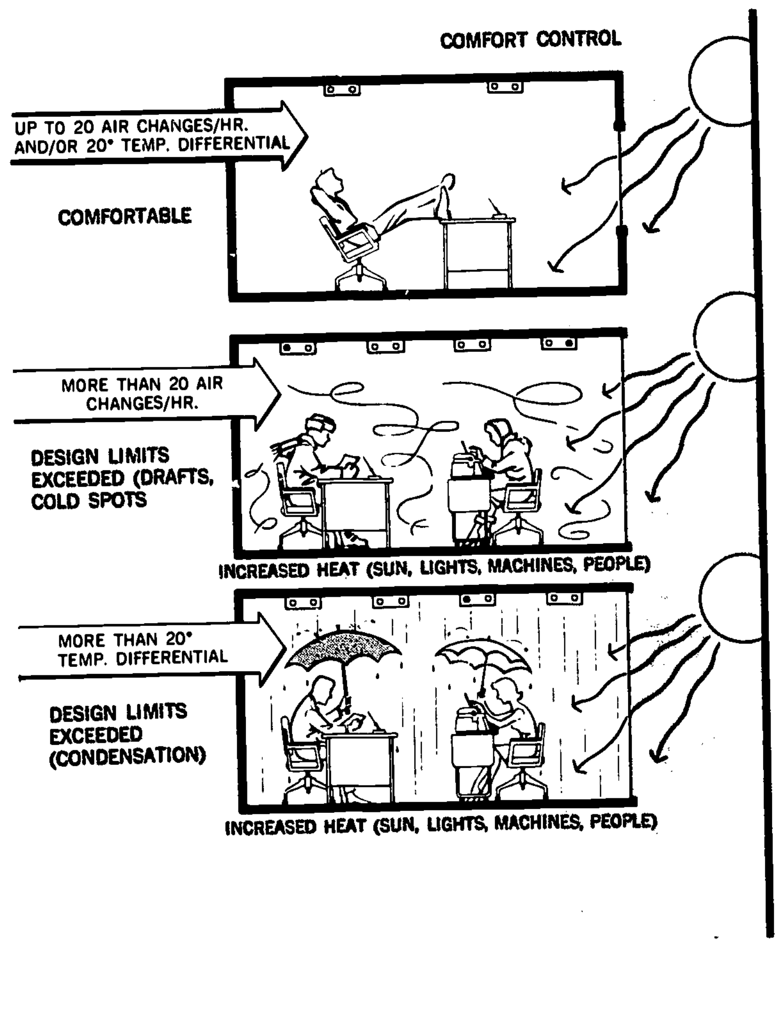


lighting for a second or third shift, the ventilation air can be shut off. This reduces the heating requirements substantially and electric heating elements can be employed to supply heat losses. Compared with fuel-fired systems, electric heating units are desirable because of their relatively low initial cost and minimum space requirements. In addition, the hours of operation of the supplementary electric heating may not be great considering the combined effects of lighting used after hours for clean-up, heat storage effects in a structure, no ventilation air with building unoccupied, and room temperature set-back at night.

The application of heat pumps may be desirable if the heat pump is used for transfer of internal heat from the parts of the building having an excess to the parts which need it. Water storage of excess energy is also practical with heat pumps and they provide the necessary cooling when needed.

The use of through-the-wall air-conditioning units or heat pumps, both with electric heating elements may also be attractive in some types of buildings and may virtually eliminate a central mechanical room.

ABOVE — Ceiling luminaires not only light but heat this modern office building during cool weather. When outside temperatures reach 20° above zero, electric wall-board heating units provide supplementary heating. *BELOW* — Air-conditioning load in an office is caused primarily by heat from the sun, lighting, people, and machines. A conventional cooling system may not be able to maintain comfort if any or all of these factors become too large. Also, if air changes exceed 20 per hour, drafts and cold spots may result. Or, if cold air introduced to a room is 20° colder than room air temperature, moisture may condense on ducts and air diffusers. Other approaches must be used in handling heat gains.



HEAT TRANSFER

Any light source contributes to the total heat of a space where it is operated. Therefore, certain relations between that and the reaction of human beings to it are important in designing electrical space conditioning systems to control the heat that lighting generates.

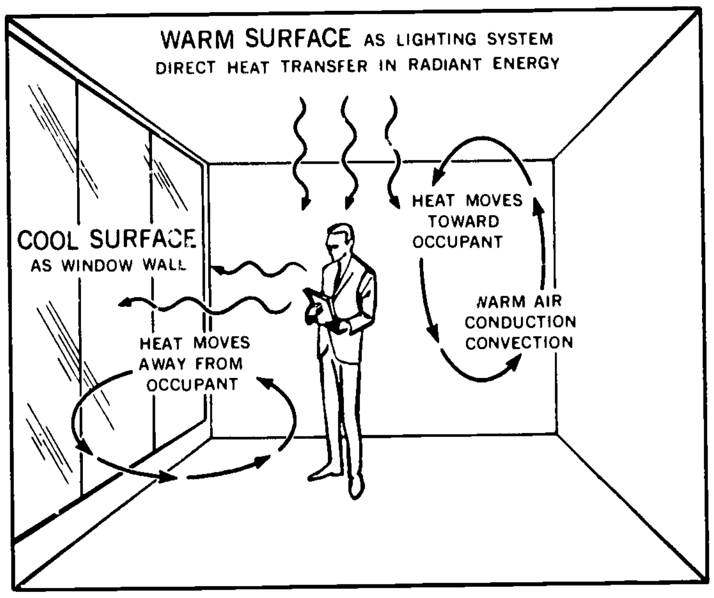
Heat transmitted through the walls and roof, heat radiated from sunlight, heat emitted by people, and the heat generated by machines and equipment all contribute to the temperature rise or drop in a room or building. The proportion of the total cooling l...d attributable to each of these sources may vary widely, depending on the type of environment.

Heat always flows from a warm object or surface to a cooler one. This flow continues until a temperature equilibrium is established between the two. If the differential is great enough, the effect may produce personal discomfort.

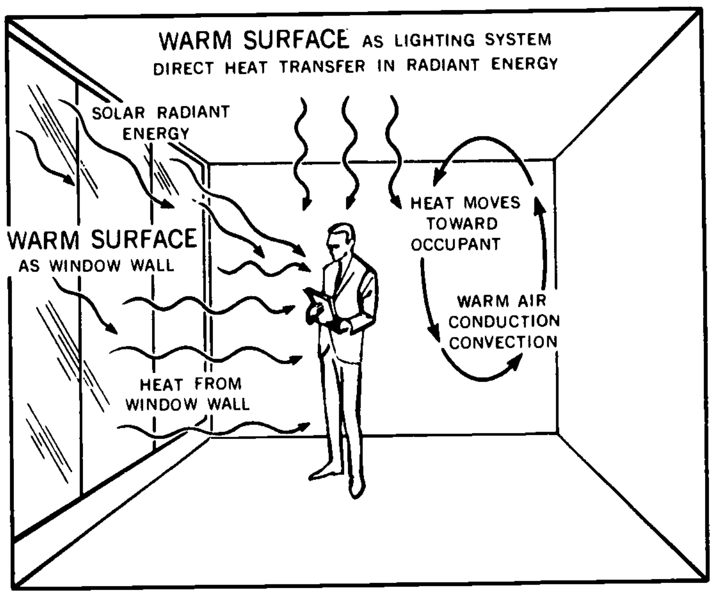
Also, the body loses heat to cooler surfaces (windows or outside walls in winter) and to cooler air. This transfer of heat cools the skin and sometimes causes discomfort. Some balance of temperature relationships is desirable to prevent discomfort.

Two types of heat are added to a building space by lighting: Conduction-convection heat and radiant heat. The relative proportions of conduction-convection and radiant heat are different for different light sources.

Heat conducted to room air causes a rise in air temperature and a convection flow of air upward since warm air is not as dense as cool air. The warmer air then moves, by means of gravity, to a cooler object where heat is again transferred by conduction, warming objects, surfaces, and occupants of the space. Because the flow of air is the key factor in the transfer of this heat, the controlled flow of heated air — to keep it away from people in the room in warm weather and to utilize it more efficiently in cold weather — is the object of integrated systems.



Characteristics of heat transfer with a cold outside window wall (above) and a solar heated window (below). Thermal comfort of people depends on heat transfer between them and their surroundings. The two principal ways of transferring heat to people is by conduction-convection through the air and directly from radiant energy.



Infrared energy follows the same path as light. It passes through air with little absorption. When it strikes a surface, it is partly absorbed and partly reflected and the object's temperature rises because of absorbed energy. Because the transfer of heat is directly between objects and surfaces rather than to the surrounding air, this type of heat is difficult to neutralize or eliminate by conventional air-conditioning or air-circulating methods. To control this type of heat, the temperature difference between the two surfaces must be reduced. This is possible by cooling the surfaces of lighting equipment or by modifying the concentration of radiant energy.

HEAT FROM LAMPS AND LUMINAIRES

The effect of lighting on the thermal aspect of an environment can be considerable since every watt of electrical energy consumed by a lamp generates heat. Light itself is a form of heat. While it does not heat air directly, it will raise the temperature of any object that absorbs it. In addition, a light source generates other forms of heat such as invisible radiant energy (infrared) plus conduction-convection.

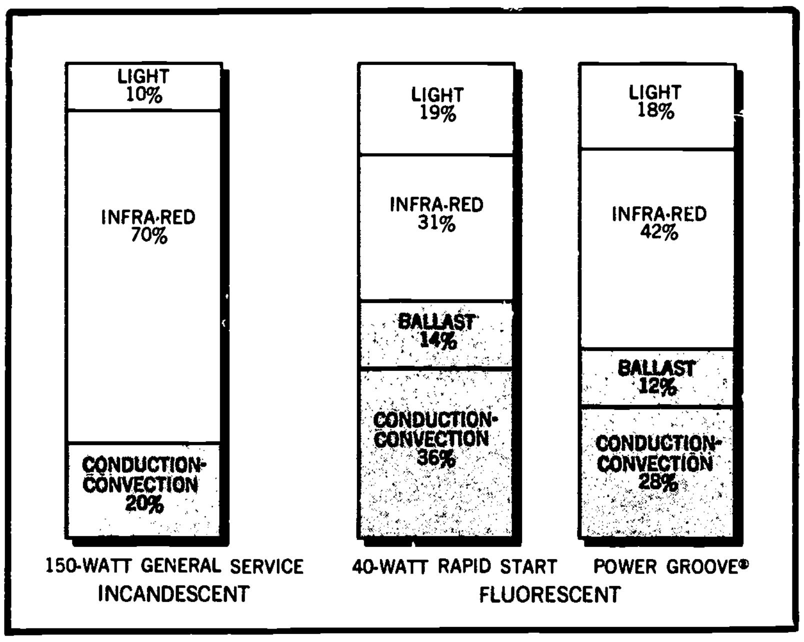
The rate at which lamps generate heat is 3.4 Btu/hr/watt of energy consumed, the same as for a conventional electric heating element. Although this factor remains constant for all light sources, it is related to "energy consumed" and not "light output," and therefore there are some sizable fundamental differences in the heat characteristics of incandescent and fluorescent lamps.

Since the fluorescent lamp has approximately three times the luminous efficacy of incandescent lamps, it will produce about one third of the heat load per lumen. Thus, the fluorescent system has an initial thermal advantage over the incandescent system.

Thus, heat build-up in the luminaires as a result of the energy dissipation by the lamp is a major factor to consider as the lighting levels and input wattages to lighting systems increase. Fortunately, there are techniques for drawing off much of this heat or otherwise controlling it before it enters the occupied space.

Since light sources are practically always used today in luminaires, the heat emission characteristics of the lamp-luminaire combination are important. When a fluorescent luminaire is first lighted, the ballast heat and the lamp conduction-convection heat are trapped — together with that part of the light and infrared which are absorbed by the reflector surfaces and louvers of the luminaire.

Most of the low-temperature infrared radiation intercepted by white-painted or anodized aluminum surfaces of a luminaire is absorbed. (See Table on Page 9.) If the luminaire is enclosed with glass or plastic panels, nearly all of the long-wave infrared energy is initially confined. As the lamp heats up, its energy is transmitted to the cooler luminaire surfaces by radiation and conduction-convection. If the heat build-up is allowed to continue, the luminaires and the adjacent ceiling area become secondary heat sources — causing heat to be carried into the occupied room by convection or re-radiation to cooler objects and surfaces. It is not unusual in unventilated lighting systems for the temperature of the luminaire surfaces to reach 120-130°F — becoming, in a sense, panel heating elements and complicating the problem of room temperature control.



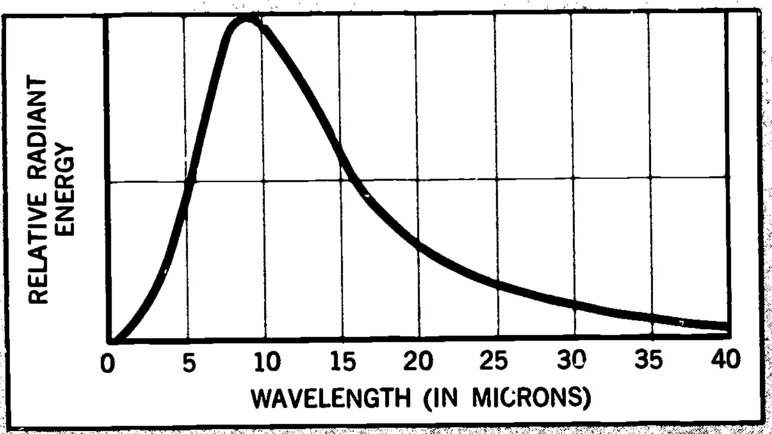
▲ Energy consumed by lamps is dissipated in several ways. Differences in heat dissipation between bare incandescent and fluorescent lamps. Comparisons are for 150-watt incandescent, 40-watt fluorescent and Power Groove fluorescent lamps.

Comparisons in heat dissipation characteristics between incandescent and fluorescent lamp luminaires when they are first turned ON assuming a luminaire efficiency of 60%. Much of the heat trapped or absorbed by the luminaire can be removed before it enters the occupied space. ▶

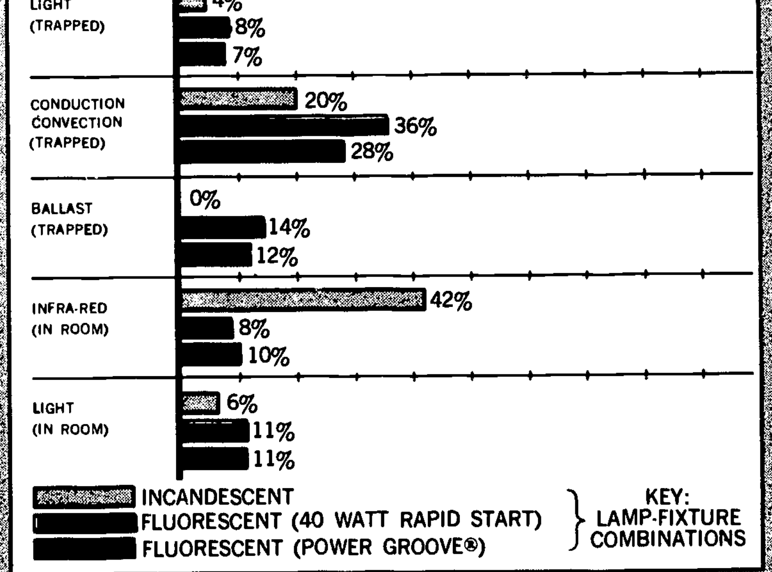
Reflectance Characteristics of Various Luminaire Materials *

Material	Reflectance at Indicated Wavelength					
	4 μ	7 μ	10 μ	12 μ	15 μ	20 μ
Polished Aluminum .	92	96	98	98	—	—
Diffuse Anodized Aluminum . . .	12	21	9	8	6	6
Synthetic Enamel on Steel	3	1	1	0	0	0
Porcelain on Steel .	5	3	9	5	6	13

***The initial energy distribution of the lamp-luminaire combination can be determined from the photometric and reflectance characteristics of the luminaire, considering the luminaire as a heat sink.**



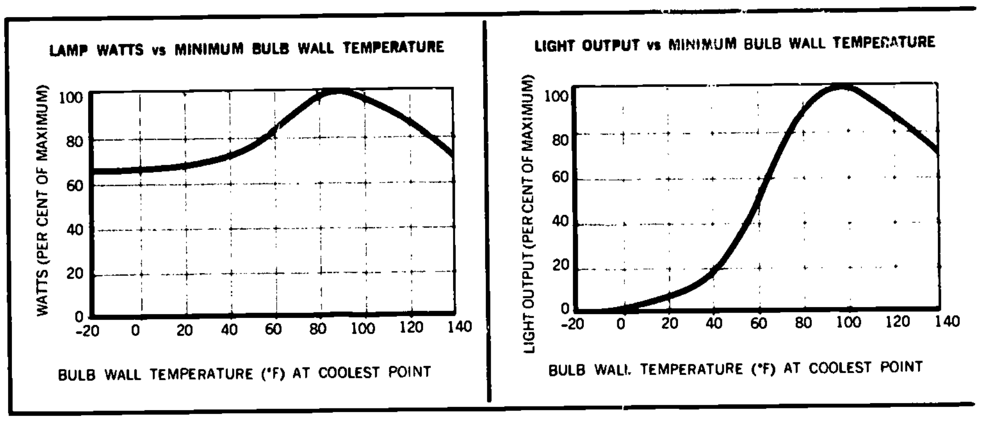
Infrared radiation from Power Groove lamps is due primarily to the bulb wall temperature which averages about 140°F. Assuming the glass bulb of the lamp to be a black body radiator, the spectral distribution of this energy is approximately as shown.



LAMP PERFORMANCE

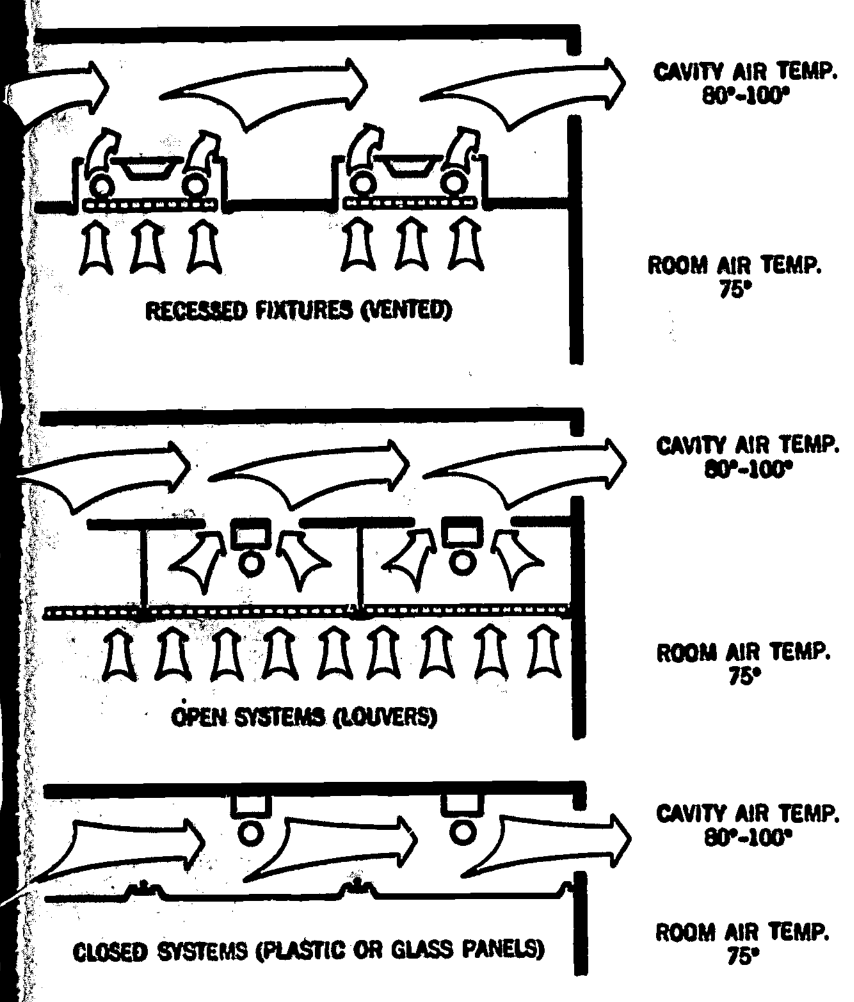
In addition to the comfort advantages to be gained by removing heat generated by light sources, improvements also are made in the efficiency of operation of the lighting system. Most recessed, surface mounted, and enclosed fluorescent luminaires produce ambient temperatures around the lamps that reduce the efficiency and, in turn, the light output substantially below rated values. For example, a standard 40-watt fluorescent lamp operated with the ambient temperature at 100°F has a light output 12% less than if operated in an ambient of 77°F.

Just as temperature affects the light output of a fluorescent lamp, it also affects the color of the light produced. About 90% of the light from a fluorescent lamp comes from the phosphor coating on the glass tube, the remainder from the mercury arc discharge within the tube. Each of these components react independently to temperature producing slight changes in color. Color differences are unlikely to be detected if all lamps in an installation are operating at approximately the same temperature. If some luminaires are in the direct draft from an air diffuser, they may appear a little different in color from others in the installation. In some types of combination luminaires and air diffusers, a technique of "spot cooling" produces a spot of approximately the same temperature for each lamp in the installation to minimize color differences. Also, cool white lamps exhibit the least color shift as a result of changes in temperature.

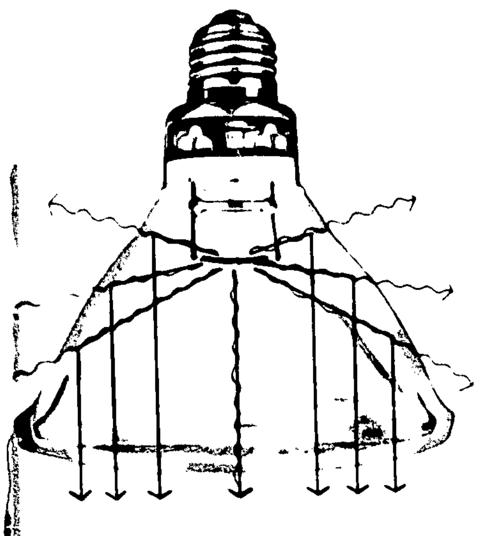


Temperature variations affect the light output and the wattage of fluorescent lamps. These curves for Power Groove lamps indicate the trend the effects take. The exact shape of the curves and the degree of response to temperature changes depend upon lamp and ballast type.

CONTROL OF LIGHTING HEAT



Three methods of lighting heat removal with air. Room air drawn through the luminaires or cavity can control a substantial quantity of heat before it enters the room. This technique can enhance thermal comfort.



"Cool Beam" incandescent lamps can substantially lower lighting heat in a space. These are molded-glass lamps having internal interference film reflectors instead of aluminum or silver reflectors. This special surface reflects light efficiently, but transmits much of the infrared out the back of the lamp. The result is about one-third as much heat energy in the lamp beam, for the same light. Use of air or other heat-removal techniques can pick up much of this energy in the luminaire before it gets into the occupied space.

A large portion of the output heat from lamp-luminaire combinations can be controlled and regulated by various ventilating and cooling techniques. If this control is achieved, the uncontrollable remaining heat can be allowed to enter the occupied space without affecting the personal comfort to any great magnitude. In fact, the amount of heat allowed to enter the space with an integrated lighting system, using today's recommended levels of illumination, can be less than would enter under inferior lighting levels if no integrated system for control were used and all of the heat were left to be handled by conventional air-conditioning systems. Through some variation or combination of the techniques explained in this section, it is possible to achieve the necessary and desired lighting heat control.

There are three general methods that can be applied to control heat at the luminaire: Regulated air flow, circulating water, and thermoelectric devices. Since most of the radiant energy is absorbed by the luminaire and converted to conduction-convection energy, it, too, can be controlled by these techniques. In many installations, from 50 to 80% of the lighting heat is available for control before it enters the occupied space.

Although air is the most common control medium, excellent opportunities for systems employing circulating water or other fluids exist. Systems now in use have tubing mechanically attached to the luminaires or integral with the luminaire reflectors to remove convection-conduction heat.

Also, the use of thermoelectric devices should not be overlooked as a possible method of controlling lighting heat. In theory, these devices can be helpful, though general application depends on future improvements in technology.

Heat Removal With Air

The use of air, circulated through lighting systems, is a widely used method of controlling lighting heat. Several techniques for regulating the lighting heat with air flow follow. The techniques vary with the lighting equipment employed and the thermal design criteria. Some of the methods provide for control and utilization of lighting heat during the heating season, but do not significantly reduce the cooling capacity required in summer. Others provide control that will both utilize heat in winter and reduce cooling tonnage in summer. All have as a common objective — reduction in lighting heat that must be controlled in the occupied space. This reduces the volume of air required for heat control in the room and carries the air which is used through a higher temperature rise, improving system efficiency and enhancing thermal comfort.

RECESSED AND SURFACE-MOUNTED LUMINAIRES

- Circulate return air through luminaires into ceiling cavity or return duct system. Air should return through all luminaires. Air path over the lamps provides maximum heat transfer in most situations.
- Circulate ventilation exhaust air through luminaires. This is that part of the return air which must be exhausted to the outside to allow for fresh make-up air. In some office buildings this may amount to from 0.2 to 0.3 cfm/sq ft. This technique may remove as much as 50% of the heat load which can be used in winter or "dumped overboard" in summer, reducing the air cooling tonnage requirements.
- Circulate return air across ceiling cavity to transfer heat from back sides of fixtures into cavity. Some techniques of luminaire design may help increase heat transfer out the back of units.
- Circulate outside air through ceiling cavity (assuming good seal between suspended ceiling and room to inhibit humidity and dirt transfer into space). This can remove some heat up to the point where the temperature of the outside air is equal to that which the cavity would attain if not ventilated. On the top floor of a building, it may also remove some of the solar heat gain through the roof.

LOUVERALL AND LUMINOUS CEILINGS

- Circulate return air through the lighting cavity. Air circulation through all parts of the cavity and around all of the lamps is essential to achieve maximum heat pick-up.
- Circulate ventilation waste air through the lighting cavity in installations where there is sufficient air volume to achieve a significant amount of control. Circulation to all parts of the cavity is desirable.
- If the lighting cavity is sealed off from the occupied space, employ a separately controlled air-circulation system. This is especially appropriate for installations such as the "clean rooms" of industry or office areas where 200 footcandles, or more, are employed.
- Where cellular-steel floor construction is employed, some of the cells may be used as ducts for return air or ventilation waste air. A pattern of openings in the ducts can be developed to achieve good circulation of air through all parts of the lighting cavity before it passes into the ducts.

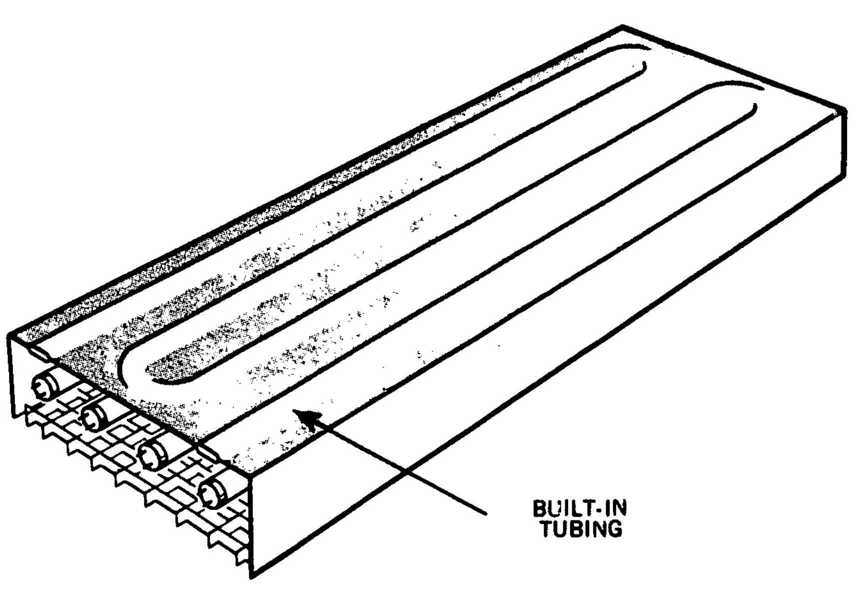
SUSPENDED LUMINAIRES

- Continuous rows of luminaires could be constructed with integral air ducts through which return air or ventilation waste air passes to pick up heat and remove it from the luminaires. New fixture designs are necessary to implement this scheme.
- Circulation of return air or ventilation waste air from the occupied space up through and around the luminaires into a ceiling return will carry off much conduction-convection heat before it enters the occupied zone or heats the ceiling to the point that it becomes a radiator. Good circulation around all luminaires and through all parts of the ceiling is essential.

The foregoing list is not meant to be all-inclusive and other techniques or combinations of techniques will, no doubt, be employed as experienced designers investigate the requirements of specific jobs.

Heat Removal With Water

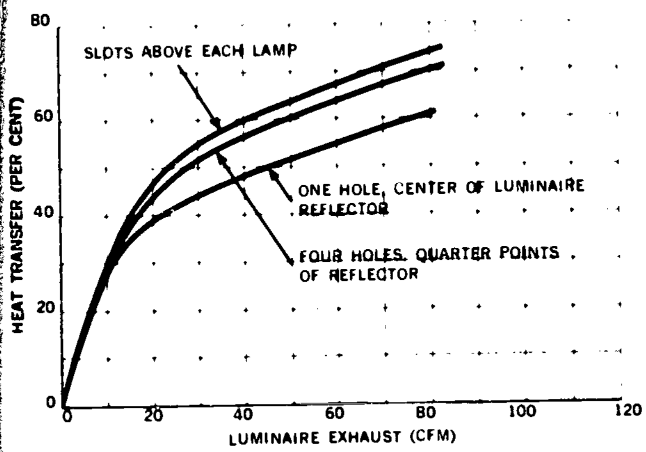
Circulating water can also be used to remove heat from luminaires before it enters the room. Water or other fluid passing through the tubing made integral with the luminaire effects the heat transfer. Total air circulation required for cooling can be reduced, but air is still needed to satisfy humidity and ventilation requirements. A system using water-cooled luminaires and water-cooled louvers at window walls is shown on Page 19.



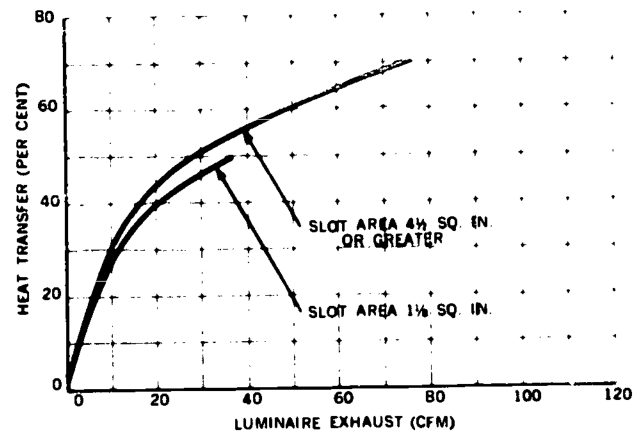
LUMINAIRE PERFORMANCE

When air is used as the heat pick-up medium for lighting, its path through luminaires is of distinct interest. One investigation to determine the most efficient air return path through troffers indicates it should be over or very near the lamps (which are the source of heat) with air motion fairly uniform through the luminaire rather than concentrated at a point. Some of the basic parameters developed through investigation follow.

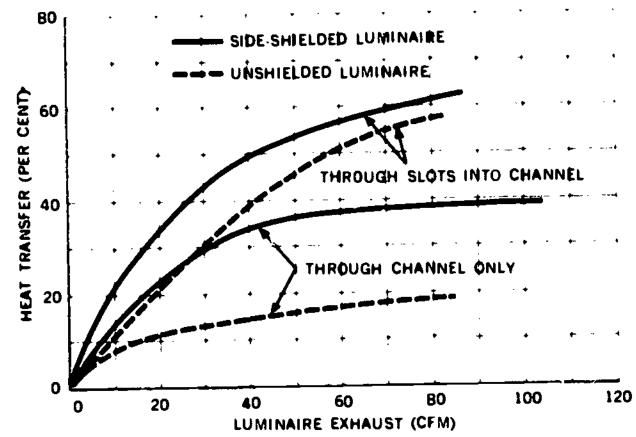
- Slot Location: Results of studies on the location and size of slots for louvered troffers indicate that narrow slots above each lamp result in 5 to 10% more heat pickup than if four holes are used at the quarter points of the fixture. Both of these slot locations are superior to one central hole in the center of the fixture. Also, little difference in heat transfer was found for slots located directly over the lamps and those located between lamps in these louvered luminaires.
- Slot Area: In general, good heat transfer can be achieved almost independently of slot area, except when the area is very small. Thus, the greatest concern with slot area is how it affects air pressure differentials between the room and ceiling cavity and in obtaining a fairly uniform air flow among luminaires in a large installation.
- Luminaire Shielding: Greater heat transfer may be obtained with a solid light-transmitting enclosure than with open louvers. This may be due to the fact that glass or plastic materials absorb the long wave infrared emitted from fluorescent lamps. An appraisal of brightness control characteristics as well as thermal properties should always be made for shielding materials under consideration in determining which material to use.
- Lamp Type: If the quantity of air available for luminaire exhaust is fixed, more heat can be brought under control when higher loaded lamps, such as the Power Groove fluorescent, are used. In addition, the exhaust temperature is higher when the higher loaded lamps are employed.



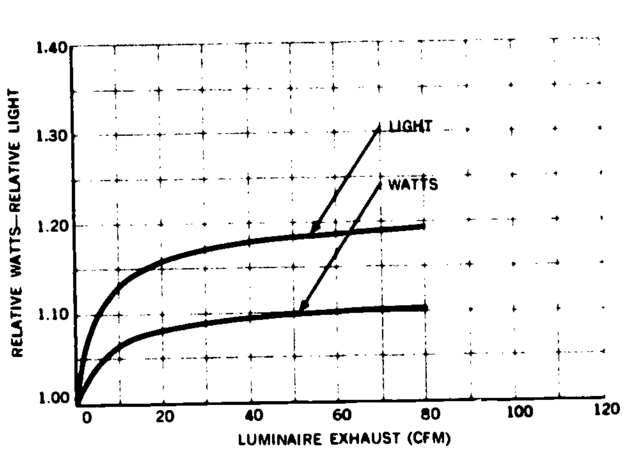
Slot location and heat transfer. A 2' x 4' metal louvered troffer indicates that slots above each lamp are most effective for heat transfer, followed closely by four holes at the quarter points of the reflector. One hole in the center of the reflector also provides substantial heat transfer, though not as great as the other two conditions. Troffers use four, 40-watt fluorescent lamps.



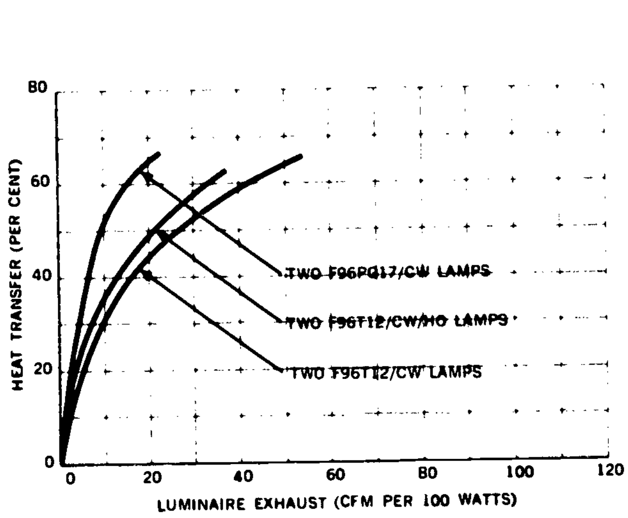
Slot area and heat transfer. Little, if any, difference in slot area effect on heat transfer is experienced unless slot area is very small. Slot areas up to 36 sq. in. were tested. Troffer, 2' x 4', had metal louvers and four, 40-watt fluorescent lamps.



Air path and heat transfer. Two experimental luminaires, one without shielding, the other with side shielding were tested. Both types of luminaires used two F96PG17 CW lamps. For both units, heat transfer was superior when the air flow path was directed through slots into the channel rather than through the channel only.



Data are for the troffer (above) using four, F-40 CW lamps and having slots above each lamp. Though luminaire input watts increase, light increases at a faster rate.



Lamp loading and heat transfer. More heat can be brought under control when high output lamps (800 ma) or Power Groove lamps (1500 ma) are used. Data are for an experimental luminaire having side shielding with air flow through slots in the reflector into the channel of the luminaire.

SYSTEMS

To capitalize most fully on the thermal properties of lamps, a suitable heat control method for lighting should be incorporated with the over-all heating and cooling design. Several possibilities are suggested in this publication. Others will, no doubt, occur to experienced designers.

The particular approach used depends on many variables such as the number of occupants of the space under consideration and the requirements for ventilation air, the use of the space, the presence of energy sources other than lighting, the type of lamps and lighting equipment employed, the watts/sq ft load for lighting, etc.

Benefits being experienced in electrical space conditioning designs have to do with both the quality of the thermal environment and economic factors. While it is difficult to generalize because of the great number of variables, economic benefits from the application of electrical space conditioning principles should be experienced when lighting is of the order of 4 to 5 watts/sq ft or higher. When lighting exceeds 9 or 10 watt/sq ft, ESC principles need to be employed if only for reasons of thermal comfort and the avoidance of radiant effects.

CONVENTIONAL SYSTEMS — A BENCHMARK

A conventional all-air system for heating and cooling may have these characteristics:

1. An air-conditioning system supplies the required amount of warm or cool air, at the proper temperature, to the occupied space. 2. All air is returned to the central system from the room except for an amount exhausted to the outside (frequently through toilet rooms) to satisfy ventilation requirements. 3. Fresh air from outdoors is supplied to the central system to make up for the exhausted air.

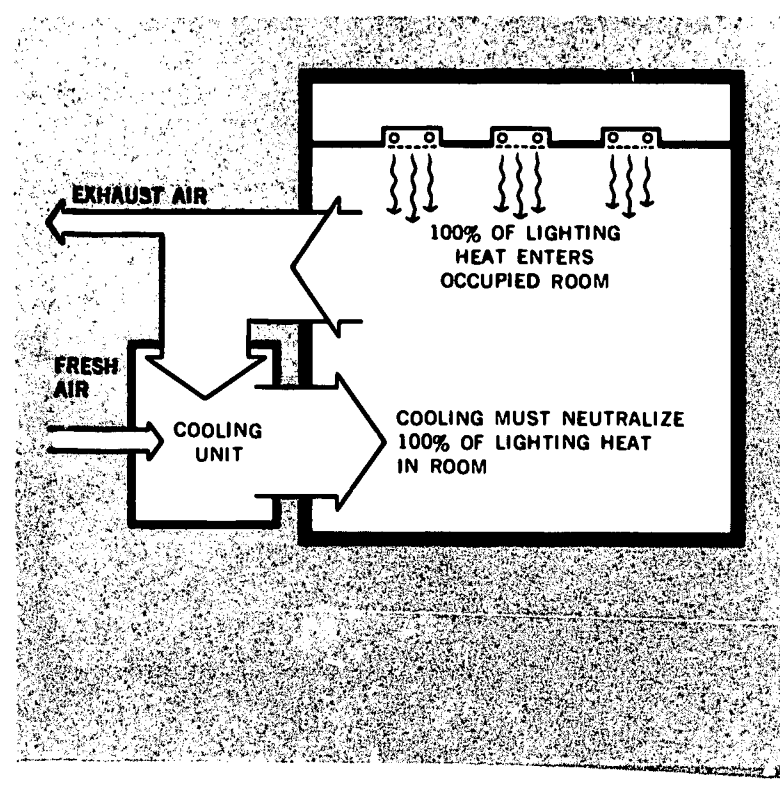
With the conventional system of air conditioning, the following results are realized:

1. All of the heat from the light sources is introduced into the occupied space and, in the cooling season, must be neutralized in the room along with heat gains from the sun, people, and machines. 2. Light output and wattage input to the fluorescent luminaires may be substantially lower than rated values because of heat build-up within the units. 3. The temperature of the luminaire surfaces may be raised to a level where they produce noticeable radiant heating effects and corresponding discomfort for the room occupants.

As an example of the requirements placed on conventional systems, if the walls are 35% glass with Venetian blinds for solar heat control, a lighting load of 6 watts/sq ft may account for 35 to 40% of the cooling load.

These characteristics and effects hold for conventional systems regardless of the type of luminaire — recessed, surface-mounted, enclosed, or louverall and luminous ceilings. For suspended open-type luminaires which permit free circulation of air, light output and lamp wattage may be near rated values if room temperature is maintained around 75°F.

Conventional approach to lighting and cooling with air conditioning system supplying all of the air to the room. Result: Cooling must neutralize all of the lighting heat in the room. Some air is exhausted from the return system and an equal amount of fresh air is brought in from outside to meet ventilation requirements.



TOTAL RETURN SYSTEMS

Total return electrical space conditioning systems have the following operating characteristics: 1. Air is introduced to the room conventionally through a pattern of air diffusers. 2. All of the room air is returned to the cooling unit through the luminaires. 3. The air for ventilation purposes is exhausted outside. The remaining air may be recycled or exhausted, either entirely or partially, depending upon outdoor temperature and humidity conditions.

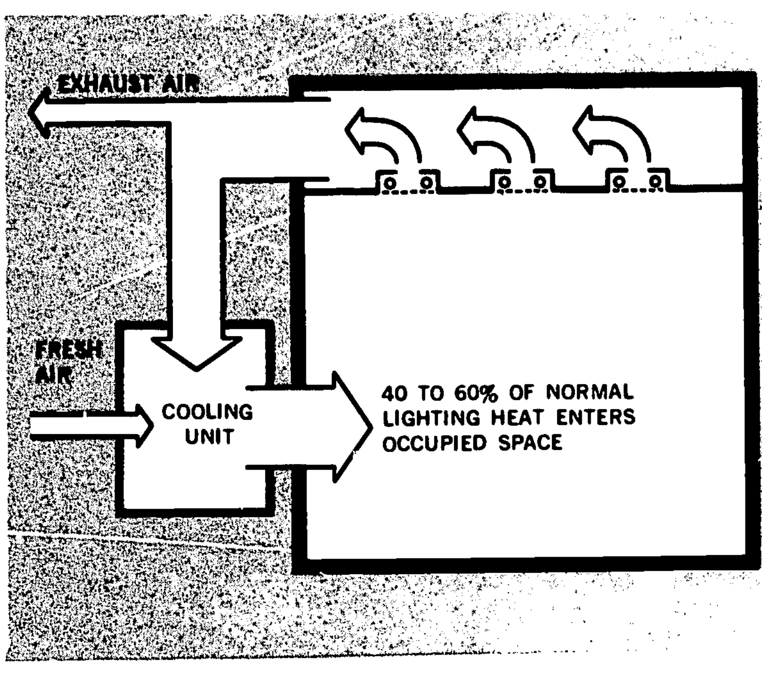
Results achieved by using this method are:

1. Compared to all systems, total return provides greatest increase in luminaire light output, as well as the lowest overall cost of light. 2. Maximum amount of lighting heat is under control while requiring the fewest air changes. 3. Lowest temperature of luminaire surfaces and minimum radiant effects. 4. Little effect on cooling system tonnage.

The reduction in air changes can be of considerable significance, with regard to both comfort and economics, especially in buildings with large areas of glass and high solar heat gain. Such buildings may exceed the capability of air systems to handle heat gains without introducing drafts or condensation and thermal discomfort.

To demonstrate the characteristics and advantages of the total return system, several typical design examples are analyzed.

Total return electrical space conditioning system. Air from room is returned to cooling unit through the luminaires with some of air exhausted to outside for ventilation. This system requires a minimum amount of air handling and results in the minimum amount of lighting heat entering the room.



Total return system in this all-electric building controls much of the lighting heat in the louvered luminaires which supply 150 footcandles of illumination. Air enters the rooms through linear air diffusers and is returned through all luminaires via slots from the reflectors into the ceiling cavity. From there, the air is returned to the mechanical room where a zoned system of heat pumps is employed.

An analysis of the effect of reducing the number of air changes by using a total return system is based on the following design assumptions:

1. Office has 100 sq ft of floor space and a 9-foot ceiling.
2. Outside wall of office has 50% glass.
3. Maximum sensible heat gain in occupied space with conventional lighting would be:

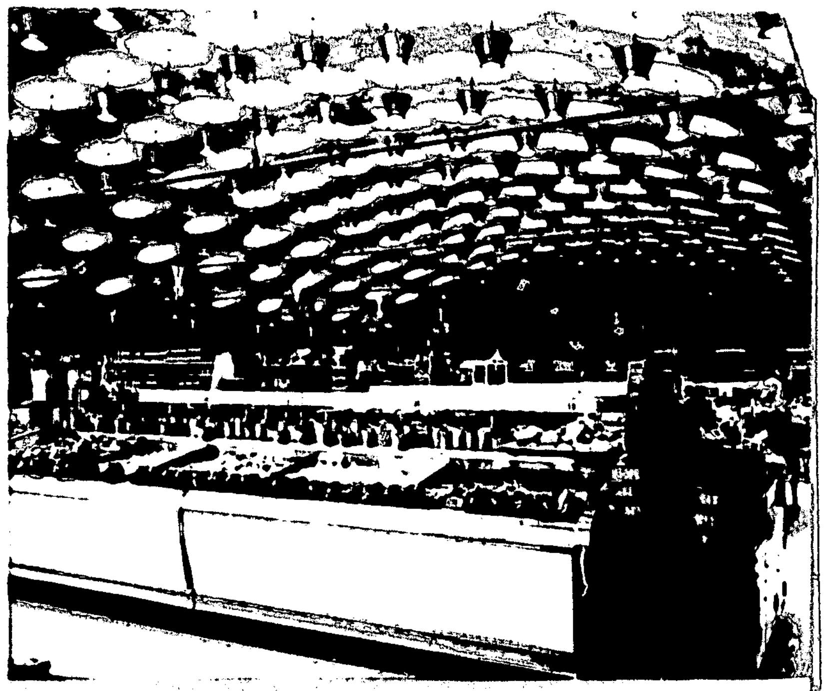
From glass and wall transmission plus solar	2350 Btu/hr
From people	220
From business machines	340
From lighting @ 6 watts/sq ft	2040
Total	4950 Btu/hr

4. Maximum sensible heat gain in occupied space using total return system would be:

From glass and wall transmission plus solar	2350 Btu/hr
From people	220
From business machines	340
From lighting @ 6 watts/sq ft with 50% picked up by return air	1020
Total	3930 Btu/hr

5. If the room is kept at 75°F and the cool air entering is kept at 55°F, then the air flow required to neutralize the heat gain in the occupied room is calculated from the formula: Heat gain = (1.08 x cfm x Temperature Rise). Thus, the air flow required under the conventional

A total return electrical space conditioning system using incandescent lighting in this supermarket supplies about 80 footcandles of general illumination plus 80% of the building's heating requirements for a design condition of −5°F. Since this contribution of lighting heat to building heat losses was considered in design, there were savings in the investment for conventional heating equipment. Air supply is through sidewall diffusers below the lighting. Air return is through the perforated cooling and high-return grills which prevents a build up of warm, stagnant air in the upper part of the room, thereby reducing ceiling temperature and improving comfort.



The lighting heat in this 200-footcandle installation (10 watts/sq ft) is the primary source of building heat, being supplemented with electric heaters only during the coldest weather. Return air is moved from the occupied space through openings in the plastic ceiling, then circulates past the lamps, picking up heat, and is moved into one of several exhaust ducts in the ceiling cavity. Return air is either recirculated, exhausted to outside, or mixed with varying proportions of outside air to obtain the most economical return mixture.

system is 230 cfm or 15 air changes per hour. And, the air flow required with the total return system is 180 cfm or 12 changes per hour.

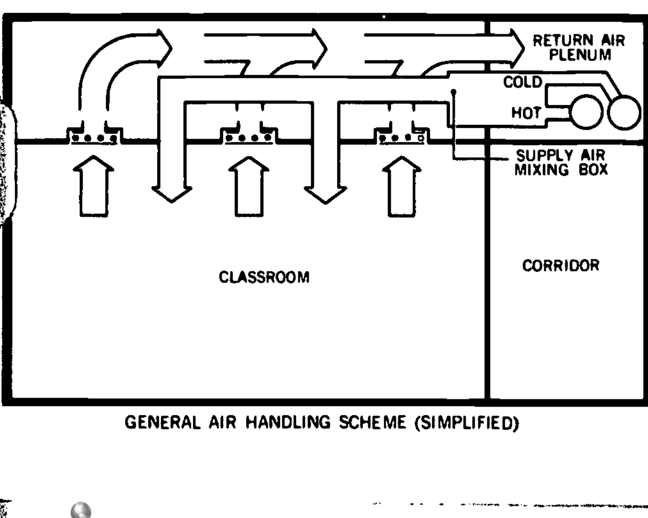
This reduction in air flow requirements could make possible a reduction in duct sizes, headroom, and fan horsepower required to comfort control the room.

It has been estimated that such a reduction in the air flow requirements could reduce the cost of air handling equipment for a multi-story building by [illegible] 12%, or about 15¢ to 20¢ per sq ft. Li[illegible]ld also be increased 10 to 15% per [illegible]ause the fluorescent lamps would be op[illegible]ler near optimum temperature conditi[illegible], floor-to-ceiling dimensions might be slightl[illegible]ed in a multi-story building.

It is not suggested that air changes be reduced below the minimum value required by code or by good practice. In the event that air changes are at minimum values, the control of lighting heat would permit temperature differentials between room air and supply air to be lowered thereby reducing compressor operating costs.

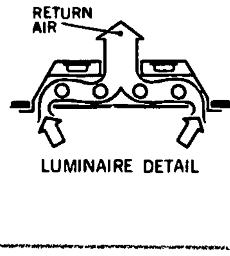
An analysis of the effect of increasing the return air temperature in a total return system is based on the following design assumptions.

1. Building has 10,000 sq ft of floor space.
2. Return air temperature for a conventional system would be 76°F.
3. Return air temperature for a total return system would be 84°F.
4. Fresh ventilation air must be introduced into the building at the rate of 0.2 cfm/sq ft. This



GENERAL AIR HANDLING SCHEME (SIMPLIFIED)

The air supply for this classroom includes a thermostatically controlled mixing box to regulate room temperature in this all-electric, year-round air conditioned school. Note the limited window area to minimize heat losses and gains and potential glare and distractions. Air is exhausted through the lighting fixtures and returned through the ceiling cavity to the central mechanical room. When there is an excess of energy from lighting and the students, it is stored in water tanks by a heat pump for use at night and on week ends.



LUMINAIRE DETAIL

amount of air would be equal to the amount of return air exhausted from the building.

5. The additional lighting heat in Btu hr discharged from the building as a result of the higher temperature exhaust air is: 1.08 x Temperature Differential x Ventilation Exhaust Rate x Floor Area. For the system described, it amounts to 17,300 Btu hr. Since one ton of refrigeration equals 12,000 Btu hr, then the amount of refrigeration saved for each 10,000 sq ft is 1.4 tons.

If the system could be designed so that the exhaust air temperature were even higher, more refrigeration could be saved. Also, where economizer units are feasible to mix various proportions of outside air and return air, the higher temperature return air may permit use of outside air at higher temperatures. This can provide additional economies in both initial and operating costs for refrigeration equipment.

BLEED-OFF SYSTEMS

Another method of integrating lighting, heating and cooling is through the use of a bleed-off system which has these characteristics: 1. Air is introduced conventionally to the room. 2. There is a conventional return for most of the air to the central system. 3. Approximately two-thirds of the air for ventilation exhaust is returned through the luminaires. 4. The remaining ventilation air is exhausted through toilet tooms and used for building pressurization.

Results from this system are: 1. Lighting heat picked up in the luminaires is not imposed on the cooling system. 2. Cooling system capacity is less than that required with conventional systems. 3. Fewer air changes are required than for conventional systems since there is less heat in the occupied space. 4. Wattage consumed by the luminaires increases, but light output increases at an even faster rate, so overall lighting efficiency is higher. 5. Temperature of luminaire surfaces is reduced.

The "bleed-off" of ventilation air through luminaires offers the greatest potential reduction in cooling capacity of any of the air-handling methods. The quantity of air available for exhaust and the number of luminaires and their heat transfer characteristics must be evaluated to determine if the "bleed-off" method is practical. High ventilation rates and efficient heat transfer, naturally, make conditions more favorable.

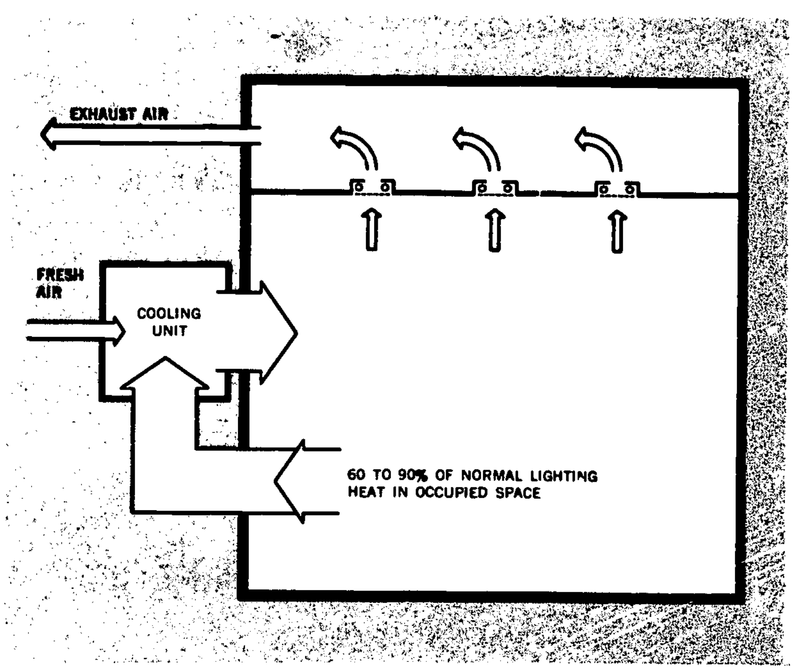
The increase in lamp efficiency due to ventilation reduces the number of luminaires required for a given level of illumination. Therefore, initial and operating costs for lighting can be reduced. During winter, the exhaust air can be used to heat incoming fresh air, resulting in another economy.

The advantages of the "bleed-off" method must be balanced against the cost of an air handling system to collect the air returned through each luminaire. This can require additional expenditure. However, in some situations, the additional cost may be negligible. For example, when supply air is conveyed through sheetmetal ducts and the principal air return is through grills in doors and through corridors (both standard practice), the cavity above the suspended acoustical ceiling can provide a convenient path for luminaire exhaust air without materially increasing air handling costs.

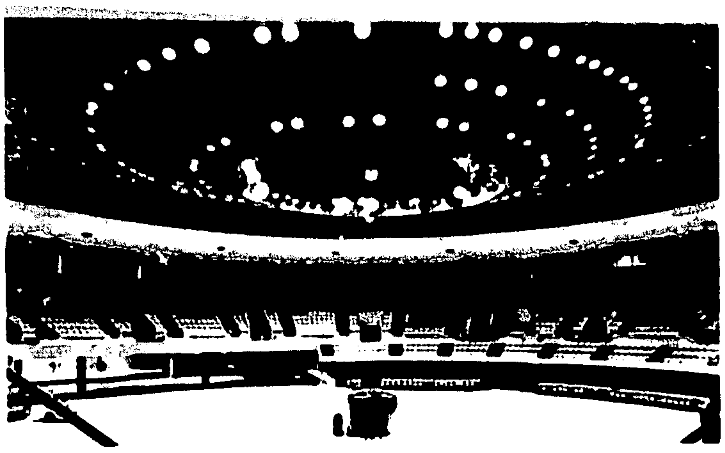
The following analysis indicates some of the features of the bleed-off systems.

An analysis of the effect of the bleed-off system on reducing the tonnage of air conditioning required for lighting is based on the following design requirements:

1. The office building is multi-story.



"Bleed-off" electrical space conditioning systems when applicable can reduce the required cooling capacity below that of conventional systems. About two-thirds of the ventilation exhaust passes through the luminaires, and the remaining one-third is available for toilet room exhaust. This system reduces the number of air changes required, luminaire surface temperature, and operating costs. Also, light output and lamp efficiency are increased.



Considerable fresh air is needed in this auditorium, so a bleed-off electrical space conditioning system was a natural. Luminaires for incandescent lamps provide about 40 footcandles of general lighting, 100 footcandles over the basketball floor, and as much as 300 footcandles in local areas. Luminaires are slotted and the ventilation exhaust air is drawn through the luminaires into the ceiling cavity, then exhausted at ports around the ceiling perimeter to the outside. System saved about 20 tons of air conditioning at $1000 per ton.

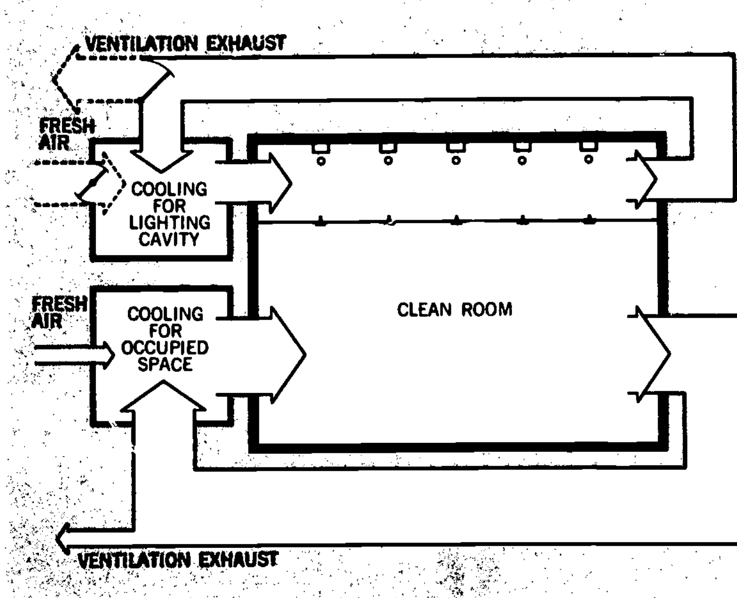
Single-story building has bleed-off system using recessed troffers with two Power Groove lamps. Units are slotted to allow 10% of the room air to be passed through the luminaire into the ceiling cavity. The remainder is returned by conventional ducts. During summer, the cavity air is exhausted to the outside by two fans installed on the roof. Fresh outside air is brought in to replace the air that is bled off. Even in summer, the outside air temperature is cooler than the luminaire-ceiling exhaust air temperature.

2. The lighting level is 5 watts/sq ft supplied by one 2′ x 4′ four-lamp troffer luminaire for each 36 sq ft.
3. Fresh air must be used for ventilation at the rate of 0.3 cfm/sq ft.
4. Of the fresh air introduced, 0.2 cfm/sq ft is available for luminaire exhaust and 0.1 cfm/sq ft is needed for toilet room exhaust and building pressurization.
5. The fresh air available for each luminaire exhaust is 0.2 x 36 = 7.2 cfm/fixture.
6. About 30% of the lighting heat or 1.5 watts/sq ft should be picked up before it enters the room by the 7.2 cfm/fixture.
7. For each 10,000 sq ft of office space, 15,000 watts of lighting heat can be controlled. This amounts to 4.3 tons of refrigeration. At $1000/-ton, this saves $4300 for each 10,000 sq ft — or 43¢ sq ft of initial cost.
8. Air changes are reduced with a resulting economy in duct size and fan horsepower.
9. Light output per luminaire is increased 8 to 10%.

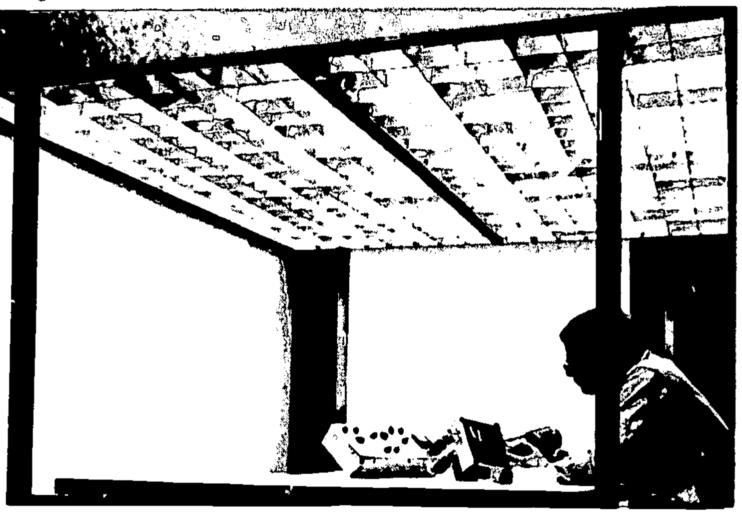
These savings must be balanced against the cost of the separate system for handling the ventilation exhaust air. If the ceiling cavity above a suspended ceiling is intended to be the path for the return air, a separate network of ducts must be used for the ventilation air. The cost of the ventilation exhaust ducting must be balanced against the savings in air conditioning to determine if there is a net gain. However, if the return path for the air is through grills in office doors and through corridors, as is often the case, the ceiling cavity can be used for the ventilation exhaust air with little additional expenditure.

SEPARATE SYSTEMS

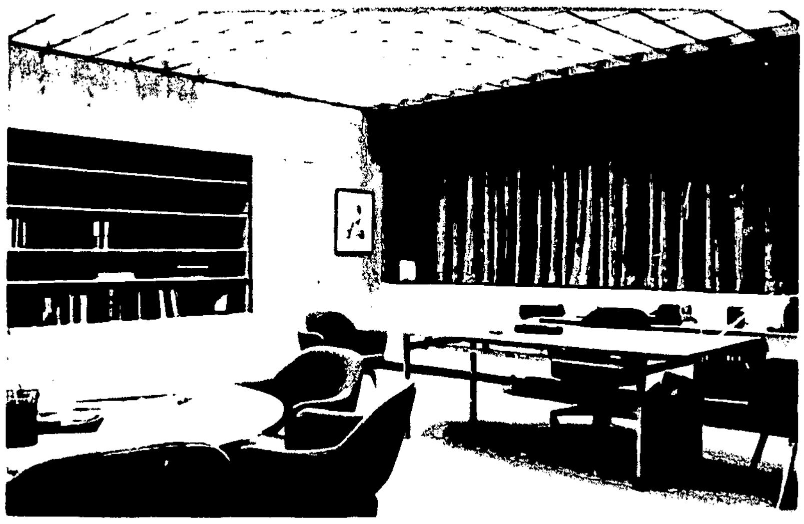
Many exacting visual tasks in factories, offices, schools, and stores are made easier by illumination supplying several hundred footcandles. The "clean" rooms of industry are one example. Some of these rooms employ lighting levels of 300 footcandles, or



Separate air system for handling the lighting heat. This system is applicable to clean rooms, or wherever higher illumination levels are needed. A separate system of air supply and return is used for the lighting system and another is used for conditioning the room itself. The automatic damper control in the lighting system exhausts all of the return air, or mixes it with a portion of outside air, depending upon the return air and outside air temperatures, to achieve the most economical mixture for recycling.



An industrial high visibility area where the lighting element has its own integrally mounted air conditioning unit. Conditioned air is supplied along the center line of the element and returned through slots in the luminaire reflectors. Power Groove lamps spaced 8 inches apart supply about 600 footcandles of illumination.



This office has 450 footcandles of comfortable illumination and a lighting system that is an important architectural element. Thermal requirements for the room and the lighting cavity are handled separately. About ⅔ of the lighting load is removed from the ceiling cavity so that only ⅓ of the lighting heat load enters the occupied space.

more, because of the demanding visual performance required. Also, because of the need for exceptionally clean air, any reduction in heat gain in the room means less of this expensive air is needed to maintain thermal comfort.

Therefore, getting the lighting heat under control has much to offer. One of the most practical ways to meet these requirements is with a separate cooling system for the lighting system. This permits the air and cooling requirements to be met efficiently, especially if a luminous ceiling or recessed lighting is employed which can be sealed off from the super-clean space. Fluorescent lamps will also benefit due to more favorable operating temperatures and whatever light is needed can be provided more efficiently. Another area in which there are definite benefits is in the regulation of the radiant environment of the worker. At higher illumination levels, radiant effects could be produced due to higher ceiling and luminaire temperatures which could create discomfort for the individual and raise the temperature of the surfaces in the space — table tops, reflectors, etc. — above a comfortable "touch" level. With a separate system, much of this lighting heat is evacuated before it can create disturbing radiant temperatures.

An analysis of a specific condition will demonstrate the advantages of this system. This analysis is based on the following design assumptions:

1. The "super-clean" room has 1000 sq ft of floor space and a 9-foot ceiling.
2. The room is an interior one, devoid of solar effects, and thus, no solar thermal load is experienced.
3. The desired lighting of 20 watts/sq ft is supplied through a luminous ceiling.
4. The sensible heat gain in the clean room using a conventional system would be:

From people (6)	1320 Btu/hr
From electrical equipment	5100
From lighting	68000
Total	74420 Btu/hr

5. This heat gain would require 3440 cfm of air or 23 air changes per hour assuming a 20°F temperature rise for the air supply.
6. The heat gain in the clean room using a separate system that would capture 60% of the lighting heat in the ceiling before it enters the room would be:

From people (6)	1320 Btu/hr
From electrical equipment	5100
From lighting	27200
Total	33620 Btu/hr

7. This heat gain with the separate system would require 1560 cfm of air or 10.4 air changes per hour assuming a 20°F temperature rise for the air supply.

From this analysis, the number of air changes per hour has been cut by 55% reducing the volume of expensive, super-clean air required and the possibilities for drafts and personnel discomfort. Also, with 60% of the lighting heat trapped and taken off, the radiant heating to the people and surfaces is considerably reduced. Note that the amount of refrigeration tonnage is not reduced, since the separate cooling system takes care of the lighting heat picked up in the ceiling cavity, and the room system takes care of lighting heat in the occupied space. But there are some economies as well as better comfort in doing it this way, and all the heat can be useful in other parts of the building in winter.

WATER AND AIR SYSTEMS

In today's modern buildings, the principal energy sources acting on the environments are lighting and solar. Minimizing solar effects could involve more compact building design, fewer windows (or none at all), wide building overhangs, reduced transmission or reflecting glass, window shielding devices, etc. ESC principles presented so far have been devoted to minimizing the impact of lighting energy on the environment, so that the other factors may be handled with familiar approaches regardless of building design. However, a more comprehensive approach would involve control and utilization of "Total Energy."

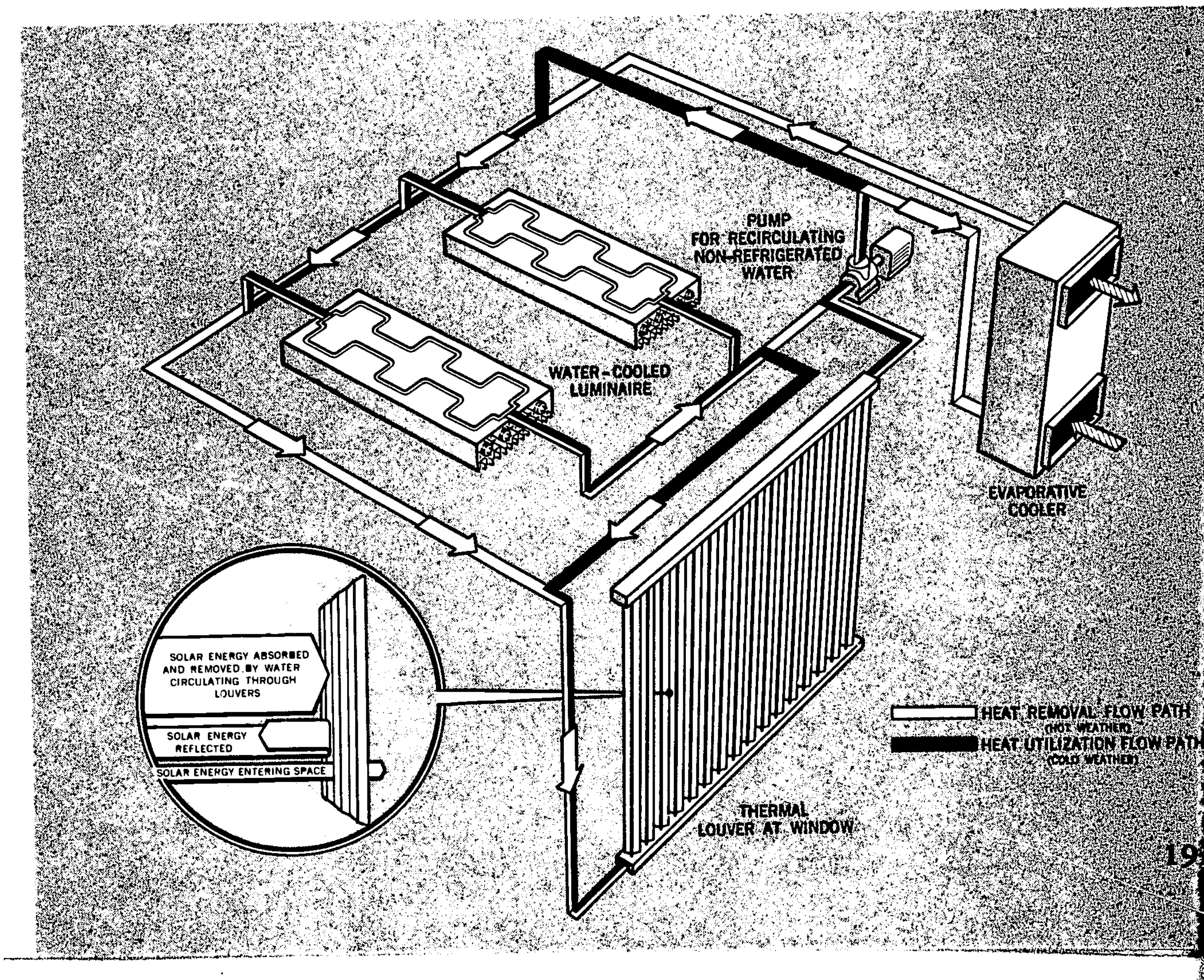
An all-electric environmental system has been developed which involves control not only of lighting heat but also solar heat. It uses nonrefrigerated circulating water in the luminaires and in "thermal louvers" at perimeter windows. The louvers provide visual shielding plus interception of solar energy. An evaporative cooler is employed with the nonrefrigerated water system.

All perimeter rooms use both water-cooled luminaires and water-cooled thermal louvers. These Venetian-blind-like assemblies next to the glass area operate automatically to intercept more solar energy as its intensity increases. Interior offices employ only the water-cooled luminaires.

One advantage of this integrated system is that it does not limit the glass area used in the design of the building. Although glass areas can be reduced or eliminated to control heat gain or loss, this approach makes maximum use of the energy generated inside and outside the building. As much as 80% of the solar heat load can be excluded from the perimeter office space. Water at 77°F removes heat generated in the lighting fixtures. The heated water is either cooled in the evaporative cooler in summer or, in winter, is supplied to the thermal louvers if there is need for heat at the perimeter. The typical temperature range of the nonrefrigerated water is sufficient to offset heat losses through the glass windows during winter or to remove solar heat during summer.

While this system uses water for heat transfer and control, it does not eliminate air for cooling, ventilation and humidity control. It also requires a method of cooling that portion of lighting and solar energy (plus other heat gains) which enter the occupied space. However, the volume of air needed to serve these requirements is smaller than an all-air system with corresponding reductions in duct size, building volume, and fan horsepower.

Electrical space conditioning system using recirculated nonrefrigerated water to pick up a large portion of the heat from the sun and lighting fixtures before that heat enters the occupied space. In the summer, 77°F water is sent directly to the lighting fixtures and directly to window louvers which are all operated in parallel fluid circuits. After the water is warmed by the heat from the lighting fixtures and heat from the sun, the water is cooled back down to 77°F by an evaporative cooler and recirculated. In the winter, 77°F water is circulated through the lighting fixtures first and the heated output water from the fixtures is then fed to window louvers in areas of the building where additional heat is needed. The louvers serve as thermal barriers in both summer and winter.

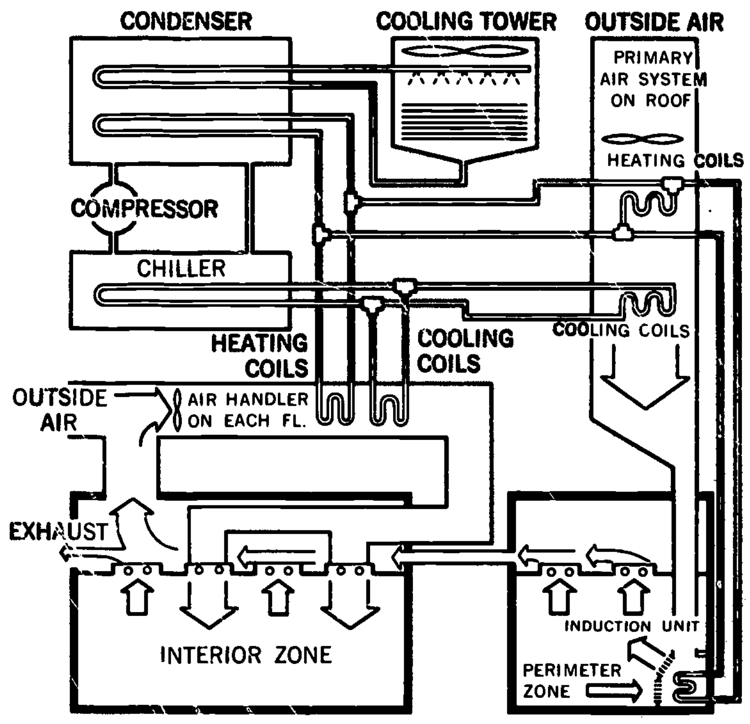


ALL-ELECTRIC SYSTEM COMPONENTS

Electrical space conditioning involves coordination of the entire mechanical and electrical systems of a structure. Lighting may be one of the significant energy sources within a structure. It is usually installed to distribute its flux fairly uniformly through a building, and, when the lighting heat is not controlled, it too, is distributed uniformly. Since uniform heat distribution is seldom desired, control and redistribution of the energy is a continuous requirement in most buildings.

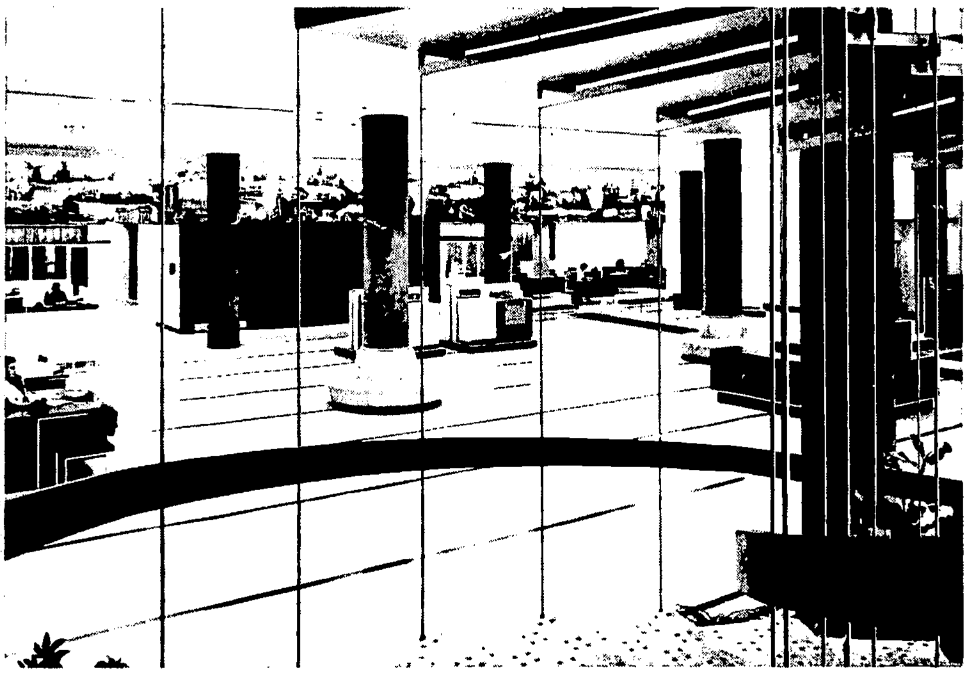
HEAT PUMPS

The heat pump is a logical device for control and redistribution of lighting heat — and storage of excess heat for future use. While heat pumps have been widely used in milder climates of the U.S.A., they have seldom been employed in commercial and industrial areas with continental climates. Lack of energy systems within such buildings to provide a substantial heating base is one reason.



One type of electrical space conditioning system using the lighting heat and heat pumps for redistribution and control of temperature in the building. System uses the exhaust through the lighting luminaires to withdraw the lighting heat and return it to the heating or cooling units.

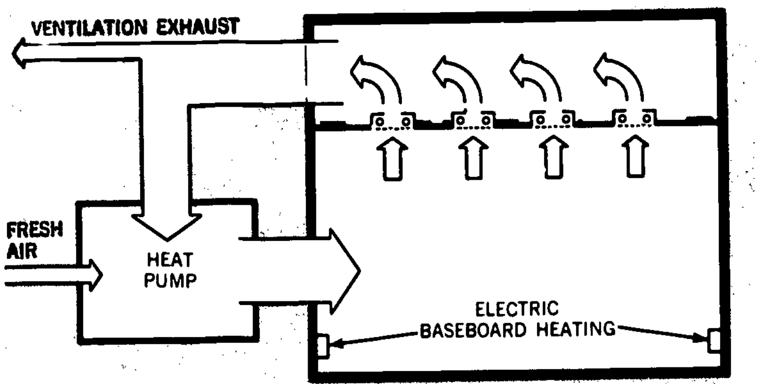
One source of energy — electricity — supplies the light, heat and air conditioning for this modern office building. Lighting and heat pumps combine to provide proper visual and thermal environments. The winter design temperature for this building is −10°F, yet the interior zones of the building do not require any supplementary heating unless the outside temperature reaches −20°F. Some of the air handling luminaires supply air — the others are used as air return units. The heat pumps are zoned, and during business hours the heat is supplied by the lighting, people, and office machines. The heat pumps remove heat from the chilled water circuits supplying the building and transfer it to the hot water circuit supplying induction units at the perimeter.



All-electric industrial plant using lighting as a key source of heat as well as providing efficient visual conditions. Manufacturing areas (above right) and offices are illuminated with 150 fc while the design area (right) has 200 fc. The combination of general fluorescent lighting and electrical baseboard heaters make the office areas comfortable in the winter. Heating in the manufacturing areas comes from: (1) General lighting employing Power Groove lamps in luminaires with 15% upward light; (2) Two forced-air electric heaters suspended from the ceiling drawing in room air close to the ceiling and directing it slightly downward just below the level of the lighting fixtures; (3) Metal sheathed electric elements in reflectors around the three outside walls of the plant for supplementary heating on workers when needed. Company management reports many advantages of this all-electric design including elimination of a chimney plus the creation of a first aid room from space originally planned for a fuel-fired furnace.

Heat pumps are able to operate efficiently as a "heat transfer" device in buildings with several zones and varying energy requirements. If there is an excess of energy in the buildings at a particular time, it can store the excess heat (usually in water storage tanks) and use it at some future time — at night and on week-ends.

Complete expense analyses on several buildings, some now in operation, some under construction have revealed heat pumps to be practical and economical for providing year-round air conditioning in a building lighted to current minimum standards or beyond.



Electric baseboard heating, supplementing the lighting, can supply all of the heat needed for a building. This drawing indicates the use of heat pumps to provide for best utilization of the building's internal energy.

ELECTRIC HEATING

Where the lighting heat does not produce all of the heating requirements for a building, electric heating can be used. Several forms of electric heating such as baseboard, duct, water immersion, or ceiling cable provide flexibility for supplementing the heat supplied by lighting.

Electric baseboard heaters are particularly useful in providing heat at the perimeter of a building where the greatest losses occur and in counteracting down drafts from cold windows.

If a lighting system contributes most of the heating requirements of a building during the time it is in operation, what about the time when it is not usually operating.

Many stores and office buildings have fairly long operating hours for lighting. Often lighting will be operating until 9 p.m., or later for cleaning personnel. Sometimes it's left on until midnight or later because of the value for advertising and public relations. This minimizes the length of time supplementary heating must be supplied. To further reduce requirements, ventilation air can be cut off at night. Then electric heaters may be employed, in ducts or baseboards to supply the necessary heat. Initial capital investment in electric heating is usually substantially less than with fuel-fired systems.

One all-electric building employing perimeter baseboard heating as a supplement to lighting uses the baseboard to carry the first part of the heating

Offices in an all-electric building in Great Lakes area using fluorescent lamps and quartz infrared lamps to satisfy all lighting and heating requirements. Recessed troffers with four F-40 fluorescents in most offices produce about 7 watts sq ft. Floating panel luminaires in corner offices using high output lamps 12 in. O.C. give 9.5 watts sq ft. Infrared system uses quartz lamps on variable voltage controlled by temperature sensing device in the plaster of perimeter wall.

requirements after hours. As the outside temperature drops, the interior circuit of lighting closest to the window comes on. If the outside temperature drops still further, a second and then a third circuit of lighting comes on.

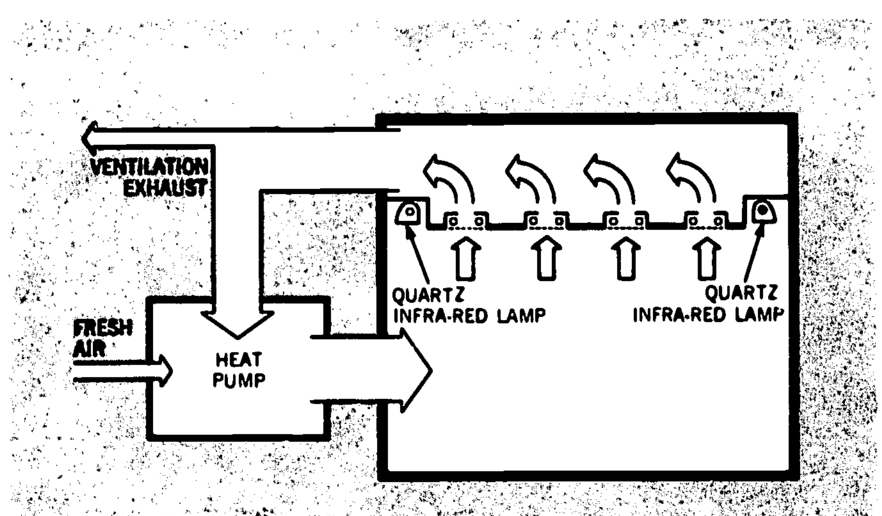
Since frequency of starting affects fluorescent lamp life, timing devices should be employed to prevent lamps from turning ON and OFF frequently. Some minimum time, such as one or two hours, should be established for the lighting system to be ON, so that cycling does not occur frequently.

Infrared lamps are highly efficient sources of radiant heat suitable for use in electrical space conditioning systems. The infrared output of these lamps responds instantaneously to changes in applied voltage making their use quite feasible for space heating. In particular, they are especially effective in neutralizing heat losses through outside walls and improving the mean radiant temperature of a space.

In one all-electric office building (shown above) having general illumination of 150 footcandles, a row of quartz infrared lamps in specially designed fixtures irradiates the inside of the perimeter wall. They are on variable voltage control governed by the wall temperature and operate on colder days to supplement the general lighting. At night, the infrared lamps handle the heating needs as far as they are capable without general lighting. If the temperature drops below the point where the infrared lamps can handle the losses, the general lighting system is turned ON for a minimum of 3 hours to serve as the basic source of heat for the building. This minimizes cycling of the fluorescent system. At still lower temperatures, the infrared lamps come ON automatically supplementing the general lighting and their supply voltage varies according to the heating requirements.

In this case, the building has masonry walls with about 35% fenestration. Obviously, this approach would not be practical for all-glass exteriors. However, even half-drawn Venetian blinds contribute to thermal comfort when irradiated with lamps. Because infrared lamps also produce light, they have an advantage over perimeter baseboard heating due to the wall lighting they provide. The warm color quality and wall brightness provides a psychological lift on cold overcast days when it is most needed. Also, since the fixtures are ceiling mounted, they do not take up floor space.

Infrared lamps can be controlled either automatically by variable voltage control units responding to a temperature sensing device buried in the wall or manually by the occupant. The latter method uses wall-mounted variable voltage transformers or silicon-controlled-rectifiers and allows the psychological advantage of offering the occupant adjustment to suit his own environmental preference. Of course, an overriding relay can provide automatic control at night.



Quartz infrared lighting units contribute to the visual as well as thermal aspects of an office environment. They supplement the heat from the general lighting system, and together supply the heating needs of the building shown above.

OTHER G-E PUBLICATIONS CONTAINING HELPFUL INFORMATION ON LAMPS AND LIGHTING

TP-101	General Lighting Design	16 pages
TP-128	Footcandles in Modern Lighting	20 pages
TP-102	School Lighting	16 pages
TP-103-R	People Heating	16 pages
TP-106	Store Lighting	24 pages
TP-108	Industrial Lighting	20 pages
TP-114	Office Lighting	24 pages
TP-109	Mercury Lamps	16 pages
TP-110	Incandescent Lamps	32 pages
TP-111	Fluorescent Lamps	24 pages

LARGE LAMP DEPARTMENT

GENERAL ELECTRIC

GENERAL ELECTRIC LARGE LAMP SALES AND SERVICE DISTRICT OFFICES

CITY	SALES DISTRICTS (To Obtain Sales and Technical Information)	ZIP No.	Telephone No.	SERVICE DISTRICTS (To Order Lamps and to Obtain Shipping Information. Local Warehouse Stocks maintained at these Points)	ZIP No.	Telephone No.
ALBANY, N. Y.	879 Madison Ave.	12208	482-3345	Buffalo Serv. Dist., 98 Hydraulic St., Buffalo, N.Y.	14210	856-0800
ATLANTA, GA.	120 Ottley Drive	30324	875-0921	120 Ottley Drive—P.O. Box 13917	30324	875-0921
BALTIMORE, MD.	1401 Parker Rd.—P.O. Box 7427	21227	242-5700	1401 Parker Rd.—P.O. Box 7427	21227	242-5700
BOSTON, MASS.	50 Industrial Pl., Newton Upper Falls, Mass.	02164	332-6200	50 Industrial Place, Newton Upper Falls, Mass.	02164	332-6200
BUFFALO, N. Y.	625 Delaware Ave.	14202	883-7381	98 Hydraulic St.	14210	856-0800
CHARLOTTE, N. C.	1001 Tuckaseegee Rd.—P.O. Box 2144	28201	376-6585	1001 Tuckaseegee Rd.—P.O. Box 2144	28201	376-6585
CHICAGO, ILL.	550 West Jackson Blvd.	60606	332-4712	4201 So. Pulaski Rd.	60632	254-6161
CINCINNATI, OHIO	990 Nassau St.	45206	961-4343	49 Central Ave.	45202	421-6810
CLEVELAND, OHIO	12910 Taft Ave.—P.O. Box 2494	44112	266-4264	12910 Taft Ave.—P.O. Box 2422	44112	266-4404
DALLAS, TEXAS	6500 Cedar Springs Rd.	75235	351-3725	6500 Cedar Springs Rd.—P.O. Box 35425	75235	351-3725
DENVER, COLO.	6501 E. 44th Ave.	80216	388-4611	6501 E. 44th Ave.	80216	388-4611
DETROIT, MICH.	15135 Hamilton Ave.	48203	883-0200	15135 Hamilton Ave.	48203	883-0200
HOUSTON, TEXAS	4219 Richmond Ave.—P.O. Box 22286	77027	667-7595	5534 Armour Dr.—P.O. Box 18265	77023	923-2549
INDIANAPOLIS, IND.	2511 E. 46 St.	46205	547-5511	Cincinnati Serv. Dist., 49 Central Ave., Cincinnati, O. 45202		421-6810
N. KANSAS CITY, MO.	200 East 16th Ave.	64116	471-3568	200 East 16th Ave.	64116	471-3568
LOS ANGELES, CALIF.	2747 South Malt Ave.	90022	723-2541	2747 South Malt Ave.	90022	723-2541
MEMPHIS, TENN.	2011 So. Latham St.	38109	948-2642	2021 So. Latham St.	38109	948-2642
MIAMI, FLA.	1310 N.W. 74th St.—P.O. Box 47-796	33147	757-8481	1340 N.W. 74th St.,—P.O. Box 47-796	33147	757-8481
MILWAUKEE, WIS.	5300 N. Sherman Blvd.—P.O. Box 299	53201	462-3860	5300 N. Sherman Blvd.—P.O. Box 299	53201	462-3860
MINNEAPOLIS, MINN.	500 Stinson Blvd.	55413	331-4050	500 Stinson Blvd.	55413	331-4050
NEWARK, N. J.	26 Washington St., East Orange, N.J.	07017	824-5200	133 Boyd St.	07103	824-5200
NEW HAVEN, CONN.	135 College St.	06510	562-9828	N.Y. Serv. Dist., 75-11 Woodhaven Blvd., Glendale, N.Y. 11227		896-6000
NEW ORLEANS, LA.	4800 River Rd.—P.O. Box 10236	70121	835-6421	4800 River Rd.—P.O. Box 10236	70121	835-6421
NEW YORK, N. Y.	219 East 42 Street	10017	751-1311	75-11 Woodhaven Blvd., Glendale, N.Y.	11227	896-6000
OAKLAND, CALIF.	999 - 98th Ave.	94603	569-3422	999 - 98th Ave.	94603	569-3422
PHILADELPHIA, PA.	Rt. 202 at Expressway, P.O. Box 299 King of Prussia, Pa.	19406	688-5900	Rt. 202 at Expressway, P.O. Box 299 King of Prussia, Pa.	19406	688-5900
PITTSBURGH, PA.	238 W. Carson St.	15219	471-9050	238 W. Carson St.	15219	471-9050
PORTLAND, ORE.	2800 N.W. Nela St.	97210	223-2101	2800 N.W. Nela St.	97210	223-2101
RICHMOND, VA.	1510 Willow Lawn Drive, P.O. Box 8627	23226	282-7644	Baltimore Serv. Dist., P.O. Box 7427, Baltimore, Md. 21227		242-5700
ROCK ISLAND, ILL.	101-31st Ave.—P.O. Box 66	61202	788-3405	Milwaukee Serv. Dist., 5300 N. Sherman Blvd. Milwaukee, Wis.—P.O. Box 299	53201	462-3860
SEATTLE, WASH.	2400 Sixth Ave., South	98134	622-8081	2400 Sixth Ave., South	98134	622-8081
ST. LOUIS, MO.	1530 Fairview Ave.	63132	429-6930	1530 Fairview Ave.	63132	429-6930
TAMPA, FLA.	815 North 26th St.—P.O. Box 5147	33605	248-1171	815 North 26th St.—P.O. Box 5147	33605	248-4174

In addition to the Sales District Headquarters cities listed above, G-E Lamp Salesmen are resident in 93 other cities. Consult your telephone directory under General Electric Company Lamp Division.

General Offices: Nela Park, Cleveland, Ohio 44112

TP-126
MARCH, 1966