



DELTA  
**Portfolio**

Demonstration and Evaluation of Lighting Technologies and Applications ▲ Lighting Case Studies

**BALLSTON SPA HIGH SCHOOL**  
Ballston Spa, New York

Site Sponsor:  
New York State  
Energy Research and  
Development Authority

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# Project Profile



In September 1998 Ballston Spa Central School District opened its new public high school. This 235,000 ft<sup>2</sup> (22,000 m<sup>2</sup>) school contains classrooms, a library, an auditorium, a gymnasium, a cafeteria, art and music rooms, and many other facilities common in high schools. Most of the 1,200 students are 14 to 18 years old.

DELTA evaluated three types of spaces in this school: the cafeteria, the library, and the art rooms. The cafeteria and library were chosen for evaluation because they were considered to be feature spaces by the project architects. The art rooms were chosen because of the lighting system's flexibility.

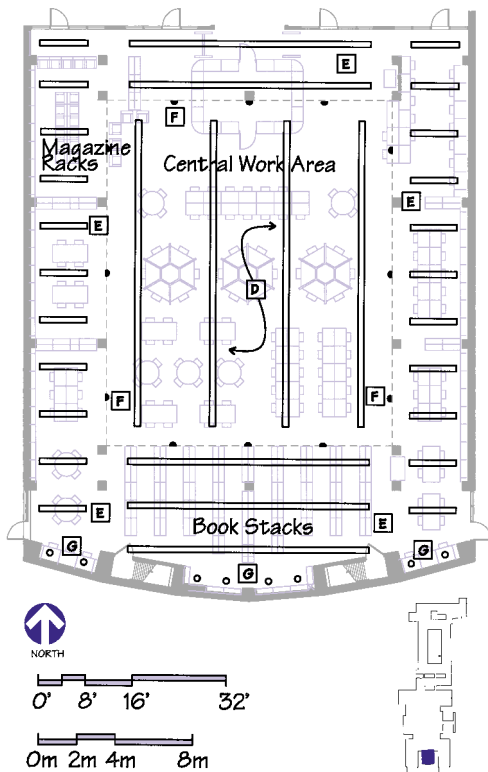
## *Lighting Objectives*

- Provide good task visibility and visual comfort
- Minimize energy use
- Provide flexibility
- Provide visual interest

## *Lighting and Control Features*

- **Task Visibility and Visual Comfort.** Suspended indirect luminaires in all three types of spaces reflect light off the ceiling, providing uniform, adequate illumination without glare. Library and art room windows have shades to control solar glare.
- **Energy Use.** T8 lamps with electronic ballasts minimize power demand. A computerized energy management system (EMS) switches lights off in various parts of the school at scheduled times. Daylight from large windows in the art rooms allow electric lights to be switched off.
- **Flexibility.** Manual switches allow occupants to change the number of lamps operating in the cafeteria and art rooms, to provide a variety of light levels. Dimmable track lighting in the art rooms can be reconfigured for displays and art activities. Window blinds control the amount and distribution of daylight in the library and art rooms. The EMS controller enables rescheduling of lighting patterns for the entire building.
- **Visual Interest.** Wall sconces in the cafeteria and library provide visual interest. The underside of indirect luminaires have slots to add some brightness to the luminaire itself. Windows provide variation in light distribution.

## Library



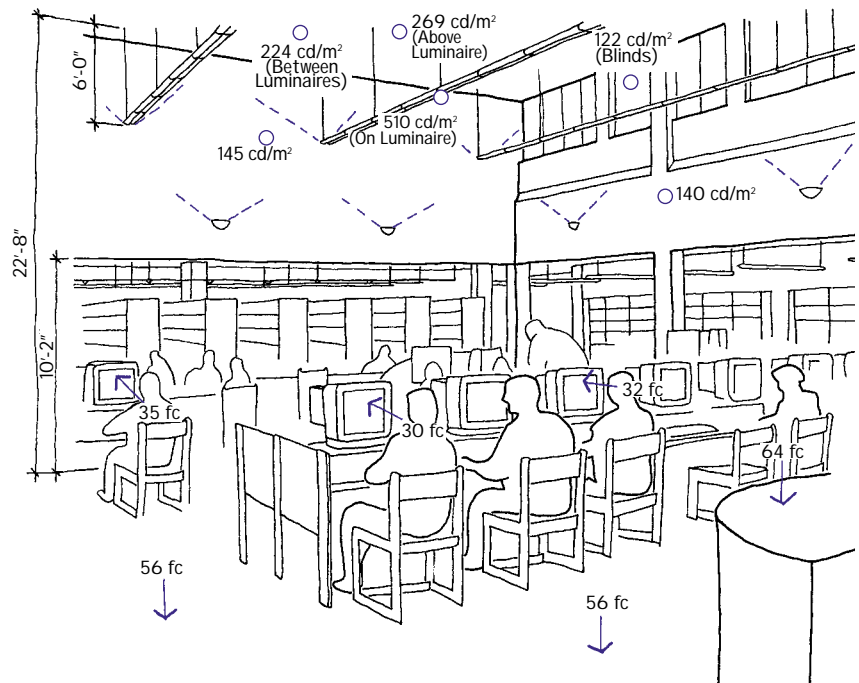
**D** **E** **F** **G**

See back cover flap for *Specifications*

The library is organized around a central work area with a high ceiling [22'-8" (6.9 m)]. This central area has desks and computer stations, and is surrounded by book stacks and magazine racks under a lower ceiling [10'-2" (3.1 m)]. In keeping with the cheerful appearance of the school, wall and ceiling reflectances are generally high (90% for ceiling, and 78% for walls).

The only daylight admitted to the library comes through the clerestory windows, although these are frequently covered with blinds to eliminate problems with direct sunlight falling on the computers.

The average illuminance on the desks in the central work area is 70 footcandles (fc) [750 lux (lx)] with the blinds closed. The illuminance on the book stack shelves is as low as 10 fc (110 lx). Similar low illuminances were measured on sloping magazine racks (not shown in photograph).



**Perspective showing photometric measurements with all luminaires on. Measurements taken with blinds closed.**



### Library's central work area

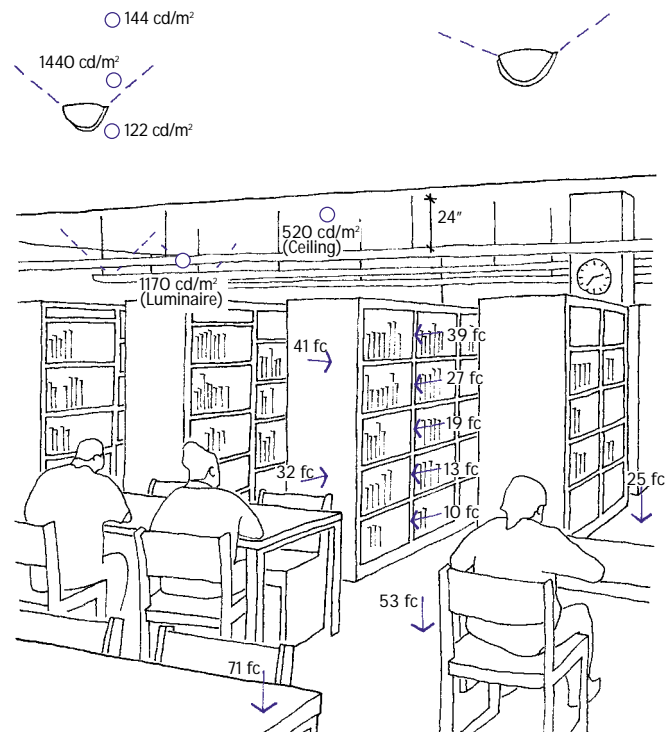
- The central work area is lighted using indirect luminaires (type D) suspended 6' (1.8 m) below the ceiling. Slot apertures in the underside of each luminaire provide visual interest.
- Decorative sconces (type F), thoughtfully spaced between ventilation diffusers, add visual interest to the plain walls of the high ceiling area.

## Library (continued)



Library's book stacks seen from central area

- Areas with lower ceilings are lighted with indirect luminaires (type E). Luminaires over the book stacks are mounted perpendicular to the aisles.
- Additional task lighting at rear wall is accomplished by recessed downlights (type G, not shown in photograph).



Perspective showing photometric measurements with all luminaires on. Measurements taken with blinds closed.

Indirect luminaires suspended six feet from the ceiling in the central area ensured an even distribution of light on the ceiling without glare or reflected images in computer screens. In the book stack area, the narrow distance between the book stacks did not allow enough light to reach the bottom of the shelves. Luminaires that direct most of the light downward, aligned with each aisle, would be a more visually effective and energy-efficient option in the book stack area.

*“The lighting in the library is just bright enough for a comfortable studying environment. I think the brightness makes the library look attractive.”*

— A student

*“(The lighting) seems to have a calming influence in my experience, because it’s not so bright.”*

— A librarian

*“The fixtures on the ceiling... sometimes students try to lob things up into them. It’s kind of a temptation.”*

— A librarian

### Student response

The majority of students thought the lighting made the library look attractive, and they found the lighting comfortable. Most students found the lighting of the library to be about the same as others they had experienced. However, there were complaints in some specific areas of the library. A quarter of the students believed that the lighting of the book stacks should be brighter, and that there was too much light in the central work area for operating the computers. This may be why a third of the students considered the lighting to be worse than the lighting of other libraries they had experienced. The librarians, however, considered the lighting to be satisfactory and reported no complaints

from the students. They wished that the controls for the blinds were more accessible so they could occasionally allow some daylight to enter the space. (DELTA notes that more daylight would probably exacerbate complaints about too much light for the computers.)

#### Compared to other school libraries, the lighting in this library is:

Better	About the same	Worse
11%	56%	33%

#### Statements about the Library (n = 122 students)

	Percentage agreeing
There is plenty of light to read even small print	91%
Overall, the lighting in this library is comfortable	87%
Colored pictures and photographs look good with this lighting	83%
The lighting makes this library look attractive	77%
There is enough light on the book shelves to find books	69%
Glossy pictures are easy to see under this lighting	68%
The difference between the lighting of the open area and the bookshelves is too much	26%
There is too much light for working on the computers	25%
The light fixtures are uncomfortably bright	24%
There is not enough light in the open area of this library	24%
The lights sometimes flicker annoyingly	23%
The windows are sometimes uncomfortably bright	21%

### Energy Analysis

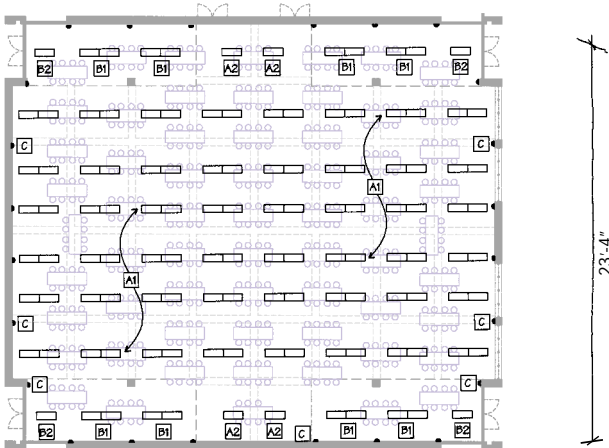
Library	Area (ft <sup>2</sup> ) <sup>†</sup>	Total LPD* (W/ft <sup>2</sup> ) <sup>†</sup>	ASHRAE/IESNA* Allowed LPD (W/ft <sup>2</sup> ) <sup>†</sup>	NY State Energy Conservation Construction Code 1991** (W/ft <sup>2</sup> ) <sup>†</sup>
<b>Central work area</b>	<b>5670</b>	<b>1.5</b>	<b>1.8</b>	<b>2.2</b>
<b>Book stacks</b>	<b>1020</b>	<b>1.9</b>	<b>1.9</b>	<b>2.2</b>

\* See *Abbreviations* on page 11

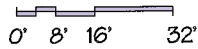
\*\* Applicable in New York State only, on a whole-building basis

<sup>†</sup> 1 ft<sup>2</sup> = 0.093 m<sup>2</sup>; 1 W/ft<sup>2</sup> = 10.76 W/m<sup>2</sup>

## Cafeteria

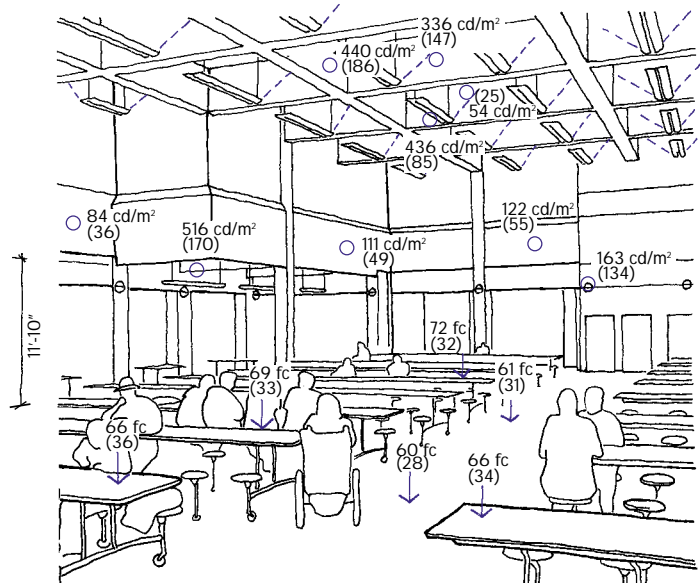


NORTH



**A1** **A2** **B1** **B2** **C**

See back cover flap for *Specifications*



**Perspective showing photometric measurements with all luminaires on, and no daylight. (Values in parentheses indicate 2 out of 5 lamps switched on for type A1 luminaires.)**

The cafeteria is more than a place for eating. It is the social center of the school, a fact reflected in the name given it by the architects – Central Square. The furniture can be rapidly removed at the end of the meal service, making the space available for activities such as cheerleading practice, exhibitions, and meetings. The cafeteria also serves as a lobby for day and evening events in the adjacent auditorium or gymnasium, and as a site for an event such as a dance.

This bright, cheerful space is characterized by high reflectances (83% for ceiling tiles, 80% for walls, and 60% for the white parts of floors).



**Cafeteria**

- Each architectural coffer is lighted with two suspended indirect luminaires (types A1 and A2). Each coffer acts as a visually comfortable light source because of its large area and diffusely-reflecting surface.
- Areas with lower ceilings are lighted with similar indirect luminaires (types B1 and B2), with fewer lamps in cross section.
- Wall sconces (type C) and colored floor tiles add visual interest to the cafeteria.
- Clerestory windows at the east side of the cafeteria (not shown in photograph) ensure some variation in lighting .

*“It’s bright and cheery!  
I feel comfortable eating in here.”*

— A student

With all the fluorescent lamps on and daylight excluded, the illuminance on the dining tables is approximately 70 fc (750 lx). These illuminances can be reduced by switching the number of lamps operating in each four-foot luminaire from 5 to 4, 3, 2, or 1. However, these multi-level switching options are not frequently used in this cafeteria, because access to the switches, located in each quadrant of the space, requires a special anti-tamper key that is available to only a few people.

### Student response

The students considered the lighting of the cafeteria to be comfortable and somewhat better than that of other cafeterias they had experienced.

The percentage of students agreeing with statements about lighting is given below.

### Compared to other school cafeterias, the lighting in this cafeteria is:

Better	About the same	Worse
33%	59%	8%

### Statements about the Cafeteria (n = 141 students)

	Percentage agreeing
There is plenty of light to see what I am eating	94%
Overall, the lighting in this cafeteria is comfortable	92%
The lighting in this cafeteria shows people's faces clearly	92%
People and food look good under this lighting	82%
There is enough light to see how clean the cafeteria is	74%
The lighting makes the cafeteria look attractive	68%
The windows are sometimes uncomfortably bright	36%
The light fixtures are uncomfortably bright	23%
The lighting in this cafeteria is too uneven	19%
There is not enough light in this cafeteria	18%
There is too much light in this cafeteria	18%
The lights sometimes flicker annoyingly	16%

### Energy Analysis

Cafeteria*	Area (ft <sup>2</sup> ) <sup>†</sup>	Total LPD** (W/ft <sup>2</sup> ) <sup>†</sup>	ASHRAE/IESNA** Allowed LPD (W/ft <sup>2</sup> ) <sup>†</sup>	NY State Energy Conservation Construction Code 1991*** (W/ft <sup>2</sup> ) <sup>†</sup>
With type A1 5 lamps on	8270	2.0	1.4	2.2
With type A1 2 lamps on	8270	1.0	1.4	2.2

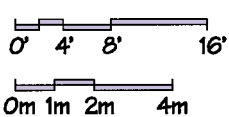
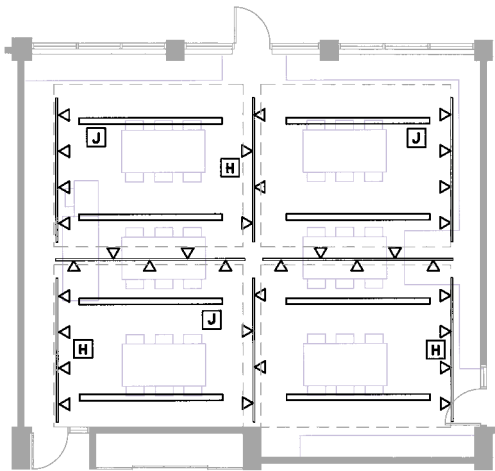
\* All lamps on in luminaire types A2, B1, B2, and C

\*\* See *Abbreviations* on page 11

\*\*\* Applicable in New York State only, on a whole-building basis

<sup>†</sup> 1 ft<sup>2</sup> = 0.093 m<sup>2</sup>; 1 W/ft<sup>2</sup> = 10.76 W/m<sup>2</sup>

## Art Rooms



See back cover flap for **Specifications**

**D**ELTA evaluated two art rooms with the same furniture layout and lighting system. The combination of daylight from large windows along the north wall and two forms of electric lighting allows considerable flexibility in the amount, distribution, and color rendering of light in the art rooms. This means the lighting can be used to reveal the important features of different types of art.

*“...the lighting is very good for doing art work.”*

— A student

*“We don’t really change the lighting in this class. It’s always the same.”*

— A student

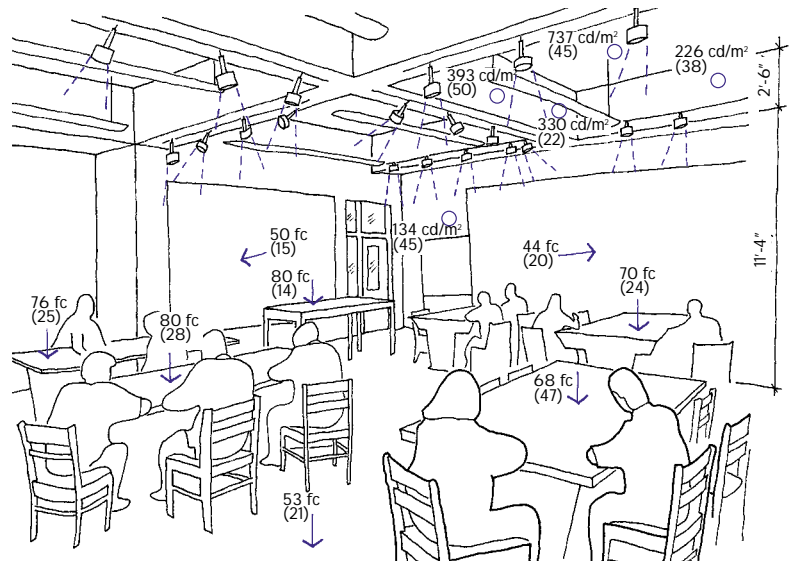
*“This (the lighting) is unbelievable — it’s great!”*

— An art teacher



**Art room with fluorescent lights only**

- Two independently controlled indirect luminaires (type J) light each coffer.
- Daylight from windows at north side of the art room is a major source of illumination.



**Perspective showing photometric measurements with all type J luminaires on, and no daylight. (Values in parentheses indicate type H tracklights only.)**



**Art room with incandescent lights only**

- Incandescent track lighting (type H) can be dimmed.

### Student and Teacher response

Nearly half of the students (45%) thought the lighting in the art rooms was better than other art rooms they had visited. In addition to the positive response of the students, the teachers also enjoyed the lighting in the art rooms. They appreciated the simplicity and flexibility of the controls. The lighting usually used in the art rooms consists of the combination of fluorescent (type J) and daylighting. Instructors use track lighting (type H) and window blinds

when lower illuminances or strong directional effects are required.

#### Compared to other school art rooms, the lighting in these art rooms is:

Better	About the same	Worse
45%	47%	8%

#### Statements about the Art Rooms (n = 47 students)

	Percentage agreeing
Colors look good under this lighting	91%
The lighting is easy to adjust for different activities	87%
Overall, the lighting in this art room is comfortable	85%
It is easy to see the details of three-dimensional objects with this lighting	83%
There is plenty of light when we need to see small details	78%
The lighting can be used to make the art look more attractive	71%
The lighting in this art room is often adjusted for different activities	51%
The light fixtures can be uncomfortably bright	23%
The windows are sometimes uncomfortably bright	21%
It is difficult to work with shiny material under this lighting	19%
There is not enough light in this art room for some activities	17%
The lights sometimes flicker annoyingly	4%

### Energy Analysis

Art rooms have a wider range of visual requirements than typical classrooms on which ASHRAE/IESNA has based its lighting power density recommendations. DELTA considers that the levels of satisfaction with the lighting of the art rooms indicate that the energy used in this lighting scheme is worthwhile to the occupants.

Art Rooms	Area (ft <sup>2</sup> ) <sup>†</sup>	Total LPD* (W/ft <sup>2</sup> ) <sup>†</sup>	ASHRAE/IESNA* Allowed LPD (W/ft <sup>2</sup> ) <sup>†</sup>	NY State Energy Conservation Construction Code 1991** (W/ft <sup>2</sup> ) <sup>†</sup>
With one type J on per coffer	2490	0.8	1.6	2.2
With both type J's on per coffer	2490	1.7	1.6	2.2
With type H incandescent only	2490	2.0	1.6	N/A***
With both systems together	2490	3.7	1.6	N/A***

\* See *Abbreviations* on page 11

\*\* Applicable in New York State only, on a whole-building basis

\*\*\* Accent lighting for art specifically excluded from Code limits

<sup>†</sup> 1 ft<sup>2</sup> = 0.093 m<sup>2</sup>; 1 W/ft<sup>2</sup> = 10.76 W/m<sup>2</sup>



# Project Evaluation

## Maintenance

The indirect luminaires in the library and cafeteria are mounted high above floor level. However, the maintenance staff have the equipment necessary to gain easy access to the luminaires. An interview with the school's custodian identified no maintenance problems with the lighting in the three areas evaluated, nor criticisms from students and teachers.

## Occupant Response

In general the people at Ballston Spa High School liked their lighting. Cafeteria and art room lighting systems were voted to be same or better than other lighting systems. Students and teachers appreciated the flexibility and control of the lighting systems. Librarians were satisfied with the lighting in the book stack area, but some students considered illuminances there to be insufficient.

## Environmental Impact

If the lighting systems were operated at reduced output as described in the Energy Impact section, reduced energy use from these spaces would result in annual lower power plant emissions (see table below).

## Energy Impact

Currently the patterns of use in the cafeteria space do not take advantage of the potential for energy savings. At full output, the lighting power density (LPD) in the cafeteria ( $2 \text{ W/ft}^2$ ) exceeds limits set in the ASHRAE/IESNA 90.1 (1999) energy standard, which is  $1.4 \text{ W/ft}^2$ . However, LPD's in the cafeteria can be reduced to well below ASHRAE/IESNA standards with the use of the switching controls. If the type A1 luminaires were switched to 2-lamps on, lighting power density would be reduced to  $1.0 \text{ W/ft}^2$ . In the art rooms, the occupants do take advantage of the switching system, saving energy; when only one luminaire is on per coffer, the lighting power density reduces to  $0.8 \text{ W/ft}^2$ . With these two reduced lighting levels in the art room and cafeteria, and the library at full output, the lighting system would save nearly \$4,500 annually, compared to spaces lighted to ASHRAE/IESNA maximums (see *Methodology* for details).

Despite the fact that some LPD values in these three isolated parts of the school approach or even exceed maximum values allowed by ASHRAE/IESNA guidelines, DELTA reasons that such energy expenditures in a few special parts of the facility have provided a visual quality that the users notice and appreciate.

### Reduced Pollution Compared to System Operating at ASHRAE/IESNA Maximum Lighting Power Density

	SO <sub>2</sub>		NO <sub>x</sub>		CO <sub>2</sub>	
	lbs	kg	lbs	kg	lbs	kg
<b>Annual savings</b>	<b>261</b>	<b>118</b>	<b>100</b>	<b>45</b>	<b>38,264</b>	<b>17,372</b>

*Sulfur dioxide (SO<sub>2</sub>) is associated with visible pollution (haze) and acid rain.*

*Nitrogen oxides (NO<sub>x</sub>) are one of the main causes of ground level ozone (smog) and acid rain.*

*Carbon dioxide (CO<sub>2</sub>) is a possible contributor to future climate changes such as global warming.*

# Methodology

This section gives details about methods and assumptions used in this publication.

## Photometric Measurements

DELTA performed illuminance and luminance measurements during the day, with the blinds closed in the library and art rooms; in the cafeteria, no blinds were available. In the cafeteria and art rooms where daylight is frequently used, measurements of daylight only were subtracted from measurements of both electric and daylight together to yield electric-only measurements.

## Surveys and Interviews

Questionnaire surveys were used to ascertain the opinions of students on the lighting quality. DELTA collected questionnaires from 141 students in the cafeteria, 122 students in the library and 47 students in the art rooms. Nearly all students approached by DELTA agreed to fill out the questionnaires. DELTA also conducted in-depth interviews with four librarians and four art teachers.

## Energy Analysis

To analyze annual electrical cost savings, DELTA interviewed Ballston Spa High School's facilities manager to obtain estimates of annual hours of use. He based his estimates on programmed schedules in the school's energy management system. Hours of use for both the cafeteria and library were assumed to be 3,468 per year. Hours of use for the art rooms were assumed to be 1,915 per year. These hours of use were multiplied by lighting wattage to determine annual energy use.

A range of LPD's were available; DELTA assumed lowest energy use for its energy impact analysis. In the library,

DELTA chose the maximum lighting wattage, since no multi-level switching capability exists in this space. In the cafeteria, DELTA assumed 2 out of 5 lamps on in type A1 luminaires, with all other luminaires fully on. Assuming available daylight in the art rooms, DELTA chose the lowest LPD, with only one fluorescent luminaire per coffer on for all hours of use.

DELTA compared these totals with ASHRAE-IESNA 90.1 (1999) standard power densities, multiplied by the total area of the rooms and hours of use listed above. The art room comparison case was assumed to be a standard classroom. Electrical cost savings for all three types of spaces were calculated, assuming an overall rate of 13¢ per kWh (including demand charge) as estimated by the school's facilities manager.

## Environmental Analysis

DELTA based the environmental impact figures in the table on page 10 on the U.S. Environmental Protection Agency's September 1996 publication, "Conservation News Online." This document is available online at <http://www.epa.gov/oaintrn/>.

## Abbreviations

Abbreviations mentioned in this report include:

LPD = Lighting Power Density

ASHRAE = American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

IESNA = Illuminating Engineering Society of North America

# Specifications

**A1**



Pendant-mounted linear fluorescent indirect luminaire painted custom purple color, 18" W x 4" D x 8' L (0.4 m x 0.1 m x 2.4 m) hung 3'-4" (1 m) from coffer ceiling. Two 4' sections join to form one 8' (2.4 m) luminaire. Five lamps in cross section, with multi-level switching. 6% downlight.

Lamps: (5) F32T8/741 per 4' (1.2 m) section, totaling 10 lamps per luminaire

Ballasts: Electronic, 277V, high power factor (HPF)

Wattage: (2) 113 W per 4-lamp ballasts and (1) 58 W per 2-lamp ballast, servicing a total of 10 lamps

**A2**

Same as (A1) except 4' (1.2 m) length.

**B1**

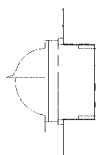
Same as (A1) except three lamps in cross section, hung 2' (0.6 m) from ceiling.



**B2**

Same as (B1) except 4' length (1.2 m).

**C**



Semi-recessed hemispherical wall sconce, 11" diam. x 6" D (280 mm x 150 mm).

Upper half painted custom purple color, lower half with white polycarbonate lens.

Lamp: CFS 21W/GR10q4/835

Ballast: Electronic, 277 V, HPF

Wattage: 23 W per 1-lamp ballast

## Specifications *(continued)*

- D** Pendant-mounted linear fluorescent indirect luminaire, painted white, 8" W x 3" D (200 mm x 80 mm). Continuous rows suspended 6' (1.8 m) from ceiling with aircraft cable. Three lamps in cross section. Rectangular perforations in underside provide 1% downlight.



Lamps: (3) F32T8/841 per 4' (1.2 m) luminaire section

Ballasts: Electronic, 277V, HPF

Wattage: 86 W per 3-lamp ballast

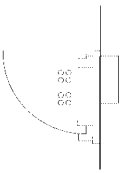
- E** Same as (D) except two lamps in cross section, suspended 2' (0.6 m) from ceiling.



Wattage: 115 W per 8' luminaire section (4-lamp ballast)



- F** Quarter-sphere compact fluorescent wall sconce, 14" diam. x 7" D (360 mm x 180 mm), with 1/2" (13 mm) offset allowing light spill around sides. Polished brass finish and clear acrylic top lens.



Lamps: (2) CFQ26W/G24q/741

Ballast: Electronic, 277V, HPF

Wattage: 50 W per 2-lamp ballast

- G** Recessed compact fluorescent downlight, 9" (230 mm) in diameter. Prismatic lensed aperture.

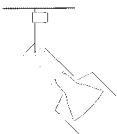


Lamps: (2) CFQ13W/G24q/827

Ballast: Electronic, 277V, HPF

Wattage: 30 W per 2-lamp ballast

- H** Track lighting, 16' (4.9 m) long, with PAR30 trackheads, painted white, and black step baffle.



Lamp: 75PAR30L/FL/Halogen

Wattage: 75 W

- J** Same as (D) except slot perforations in underside, providing 1% downlight.



## Lessons Learned

### Indirect lighting promotes visual comfort.

Indirect lighting shields the light source from view, thus reducing glare. Ceilings above the luminaire become large area light sources, and ensure high levels of brightness uniformity. Indirect lighting also provides uniform illuminance levels, except in areas with obstructions (see below). Lighting that is uniform and free of glare is visually comfortable.

### Luminaire layout and light distribution should minimize the loss of light caused by furniture obstructions.

Indirect luminaires run perpendicular to the book stacks in the library. This results in lower illuminances on the shelves than if luminaires were parallel to the aisles. Illuminances could also be increased if luminaires directed light primarily onto the shelves rather than onto the ceiling. If properly positioned, direct illumination of this type would not necessarily increase glare.

### Controls must be easily accessible to authorized personnel.

The blinds on the clerestory windows in the library are frequently closed because at certain times of the day and year, there is a problem with sun penetration. The mechanical controls used to adjust the blinds are placed high on the wall, out of the reach of the students and the staff. In the cafeteria, multi-level switching is available, but is not often used. If the need for lower illuminances has been identified in a large common space, a single control location should be designated that is secure from student interaction, yet convenient enough that faculty and staff are willing to use the system.

### Indirect lighting is a tempting place for students to deposit balls of paper.

Students sometimes throw objects into suspended indirect luminaires. The maintenance and safety implications of such behavior should be considered at the design stage.

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Type C: Noral; Types D, E, J: Peerless; Type F: Advent;

Types G, H: Lithonia

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