Sony Disc Manufacturing
Springfield, Oregon

Type:
Manufacturing Facility

Site Sponsor:
Bonneville Power Administration

Host Utility:
Springfield Utility Board
Sony Disc Manufacturing in Springfield, Oregon, opened in 1995 as a state-of-the-art manufacturing facility for digital optical discs. Operating 24 hours a day, this 324,800 square foot (30,856 square meter) facility sits on a 120-acre park-like site surrounded by forest. With 350 employees, it currently produces as many as 6.5 million discs a month.

Inside this building, a compact disc (CD) goes through the full production process. It begins with pre-mastering customer materials (music or data, for example), then mastering a “mother” disc, then producing individual masters for replicating the discs in quantity. Finally, CDs are printed with artwork and packaged for shipping.

The lighting in the manufacturing spaces was designed to accommodate the many visual tasks involved in CD production and to meet clean room standards for some of the manufacturing processes. In non-manufacturing spaces, the lighting provides good task visibility with minimal glare, while accentuating the architectural design and providing visual interest. The design team, Boucher Mouchka Larson, Architects and PAE Consulting Engineers, carefully coordinated architectural details with lighting and controls equipment.

The DELTA team evaluated several types of industrial spaces. The lighting includes glass reflector high-bay luminaires with 400-W metal halide lamps in the Warehouse. Sealed clean room troffers and louvered direct/indirect pendant luminaires using T8 fluorescent lamps and high-performance electronic ballasts are used in the Staging, Replication and Printing, Packaging, and Shipping and Receiving areas. All lighting circuits are controlled through a whole-building energy management system (EMS). The lighting power density in the industrial side of the facility is 1.04 W/ft² (11.2W/m²).

This DELTA Portfolio evaluates spaces within the manufacturing facility exclusively and does not include the office space, wellness center, dining areas, or other employee-centered areas of the building.
Lighting Objectives for the Industrial Areas

- Create work spaces with good task visibility and visual comfort for employees.
- Minimize energy use by using energy-efficient lamps, ballasts, luminaires, and controls.
- Create bright, visually stimulating spaces to help keep shift workers alert before sunrise.
- Keep initial cost of the lighting installation within budget.
- Qualify for utility-sponsored energy rebates.

Specific areas:
- Staging and Replication and Printing areas: Use luminaires that conform to clean room standards. Provide uniform lighting over floor area to accommodate frequent changes in equipment and its layout without shifting luminaires.
- Packaging: Provide evenly distributed workplane illuminance with minimal glare for a variety of packaging tasks.
- Warehouse: Provide uniform vertical illuminances on shelving in warehouse aisles to aid in reading labels on shelved materials.
- Shipping and Receiving: Provide evenly distributed illuminance for easy viewing of labeled materials loaded into and unloaded from trucks.

Lighting and Control Features

- Energy-efficient lamps and ballasts
- High-efficiency clean room luminaires
- Direct/indirect luminaires that help workspaces look bright
- EMS that permits switching off lighting circuits in unoccupied areas

Clean Room Luminaires

Manufacturing techniques for delicate electronic media such as CDs require unusually clean environments called clean rooms. In these spaces the concentration of airborne particles, temperature, and humidity are controlled to specific requirements. Workers wear special clothing that helps prevent dust, dirt, and skin particles from entering the clean room.

Clean rooms are classified according to how many particles of a specific diameter are allowed in a cubic foot of air. For example, a Class 10,000 clean room cannot have more than 10,000 particles of 5 microns or larger per cubic foot.

Luminaires for clean rooms are specially designed to permit a smooth flow of air from air-filtering systems over their surfaces. Clean room luminaires should have enclosed, gasketed, sealed designs to minimize dust, mold, and microscopic particles entering the room from the luminaire. They should also be designed to keep contaminants from the plenum from entering through holes for mounting hardware and electrical feeds. Where magnetic ballasts are used, the magnetic flux can attract dust particles. This problem can be prevented by using electronic ballasts, which do not attract dust particles, or by mounting magnetic ballasts remotely, outside the clean room.
**Project Specifications**

The principal light sources used in the Sony facility are T8 4' (1.2 m) rapid-start lamps with a color rendering index (CRI) of 75 and a correlated color temperature (CCT) of 3500 K. The warehouse luminaires use 400-W clear metal halide lamps and also have 250-W halogen lamps for instantaneous light in emergencies. The adjustable loading dock lights use 150-W PAR38/FL lamps.

All 4' fluorescent lamps are operated on low total harmonic distortion electronic ballasts for energy efficiency and minimal interference with sophisticated electronic machinery. Metal halide lamps are operated with high power factor magnetic ballasts.

**AA**

Pendant-mounted direct/indirect luminaire, 8' (2.4 m) long, with metal sides, two fluorescent lamps in cross section. Open upward, louvered downward with 45° cutoff. White-painted finish on housing and louver. Two-lamp electronic ballasts. Lamps: (2) F32T8/RE735

**BB**

Recessed 2' x 4' fluorescent luminaire with three fluorescent lamps in cross section. Flush steel door with spring latches for easy access to lamp chamber. K12 prismatic acrylic lens. Two-lamp electronic ballasts. Center lamps of adjacent luminaires tandem-wired. Lamps: (3) F32T8/RE735

**CC**

Recessed 2' x 4' fluorescent luminaire with three fluorescent lamps in cross section. Sealed and rated for Class 10,000 clean rooms. K12 prismatic acrylic lens. Two-lamp electronic ballasts. Center lamps of adjacent luminaires tandem-wired. Lamps: (3) F32T8/RE735

**DD**

Extendable-arm “dock light” with swivel-adjustment head for directing light into trucks.
Mounted to wall adjacent to loading bays, 5’ (1.5 m) above floor. Yellow-painted finish.
Lamp: 150PAR38/FL

EE
Pendant-mounted enclosed and gasketed luminaire with 22” (0.5 m) diameter prismatic glass reflector and integral magnetic ballast. Luminaire produces 18% uplight, 82% downlight with narrow distribution optics, 0.8 spacing criterion. 250-W halogen restrike lamp provided in 12% of luminaires.
Lamp: M400/U (clear) metal halide

Wattage
Input wattages for luminaires include ballast watts. Wattages are prescribed by the Oregon State Energy Code, an amended version of the Uniform Building Code’s Chapter 53, “Energy Conservation.” The Code’s tables provide input wattage values (called luminaire power) for use in energy calculations for various combinations of lamps and ballasts.

- **T8 fluorescent lamps (electronic ballast)**
  - F32T8 (4’): 114 W per 4-lamp ballast
  - F32T8 (4’): 93 W per 3-lamp ballast
  - F32T8 (4’): 57 W per 2-lamp ballast

- **Incandescent lamps**
  - 150PAR38/FL: 150 W

- **Metal halide lamps**
  - M400/U: 461 W
**Details**

**Replication and Printing Area** In this 13,600 square foot (1263 square meter) clean room, machines called solo-liners replicate CDs to exacting standards. Master discs called stampers imprint digital data onto blank CDs. The completed discs are then moved to a second bank of machines which silk-screen artwork onto them. Technicians set up, adjust, and maintain the replication machinery, and identify defective CDs. Printing operators enter codes to select ink colors for the artwork, maintain the autoroll machines, and briefly inspect the artwork of every finished CD for clarity and correct colors. Some CDs are inspected more thoroughly to catch molding defects.

*Replication area: clean room*

*Section A–A’. Printing/Replication at night in open area*

*Section B–B’. Printing/Replication at night in solo-liner area*
Recessed 2’ x 4’ clean room luminaires (type CC) with three F32T8 lamps and electronic ballasts provide ambient light. These luminaires are sealed to Class 10,000 standards to prevent adding dust to the air or disrupting air flow over surfaces in the room. Horizontal illumination in the room depends on the amount of equipment in it: in a relatively empty part of the room at night, floor illumination is between 95 and 135 footcandles (fc) (1020 to 1450 lux [lx]), but where the solo-liners are concentrated, the machinery itself blocks light and lowers illuminance on the floor to 45 to 73 fc (490 to 790 lx).

**Staging Area** Technicians bring defective discs from Replication into the Staging area to inspect and categorize the type of error that caused the defect. The technicians then identify the production problem so that they can make adjustments to the machinery. Visual tasks in this area are extremely varied, difficult, and critical. They range from spotting tiny aberrations in the CD’s surface, to viewing VDT screens and equipment monitors, to seeing through the large glass wall to monitor activity on the production floor.

Early morning sunlight enters the Staging area through high clerestory windows in the adjacent corridor for one to two hours a day most of the year. Unfortunately, the computer screens in this area face the windows. Direct sunlight bothers some technicians when it falls across their workspace or creates a bright, reflected image on their computer screens. With daylight, vertical illuminances on screens are as high as 210 fc (2300 lx). Even when there is no direct sunlight, the reflection of the clerestory windows obscures computer screens and the view into Replication. At night, however, electric lighting adds no more than 46 fc (490 lx) vertical illuminance to screens, making them much more readable.

Screen visibility varies according to the specularity (shininess) of the screen, the maximum luminance (brightness) of the screen, and the comparative luminance of the characters against their background (contrast). Highly specular screens reflect far more of the distracting window brightness than screens with anti-reflection coatings. The window reflection is also less noticeable on higher luminance screens.

Despite the reflections, technicians like being able to see the sky and tell what time of day it is, even though they don’t have a view of the ground.
Details

**Staging Area (continued)**

When daylight is not available, horizontal illuminances on both sides of the room at the 3'-6" (1.1 m) countertop are 82 to 95 fc (880 to 1030 lx), sufficient for paper tasks anywhere in the Staging area. At midmorning on a typical partly cloudy day, daylight contributes up to an additional 74 fc (800 lx) to these surfaces.

When technicians make their first check for imperfections, they hold a CD slightly above eye level, using the reflection from overhead luminaires to reveal defects on the shiny surface. They look for tiny bumps, dimples, fibers, and particles of dirt on the discs to determine if the replication machines are producing problems they must correct. Several technicians also use the halogen task light to produce a high-intensity reflection for a closer check. Technicians report that neither the overhead lighting nor the task lighting is well-suited to their inspection tasks. The DELTA team observed that the task of detecting a variety of extremely small, low-contrast details requires a variety of lighting conditions. A dedicated viewing booth would help make these flaws more visible. (See Lessons Learned.)

**Packaging Area**

Tasks in this area include inserting CDs and paper liner notes into clear plastic cases, wrapping individual cases in cellophane, boxing the cases, and preparing them for shipping. Much of the work is highly automated, but 18 employees per shift visually inspect, adjust, and stock the machinery.

The room is lighted entirely with three-lamp T8 recessed 2’ x 4’ lensed troffers (type BB) on 8’ x 8’ (2.4 x 2.4 m) centers. High-frequency electronic ballasts eliminate flicker so that moving machinery does not appear to stop or change speed. The room has no windows. Although the lighting layout is very similar to that in the adjacent Replication and Printing area, the machinery is shorter in height and spaced farther apart. As a result, the machinery blocks less of the light and the illuminance on horizontal task surfaces remains fairly high (108 to 115 fc [1160 to 1240 lx]).

**Warehouse**

The warehouse space has 35’ (11 m) ceilings. It provides storage for manufacturing materials as well as finished products. Two to four employees on each shift track inventory storage and retrieval. Their desks are located in the warehouse, and they perform both paperwork and computer screen visual tasks. Forklift operators moving materials on pallets need to read labels quickly on both pallets and the vertical shelving members.
Glass reflector luminaires (type EE) with 400-W clear metal halide lamps are pendant-mounted near the bottom chord of the ceiling trusses. The luminaires are spaced on 20’ x 20’ (6.1 x 6.1 m) centers. To avoid most of the glare and visual comfort issues associated with high-bay industrial lighting, the design team specified a white-painted ceiling and luminaires which direct 18% of their light upward. The luminance of the luminaire can be 22,000 cd/m$^2$ or higher, and when contrasted against the white ceiling, the sensation of glare is reduced, even though the contrast ratios do not change very much. The bounced light from the ceiling helps make light levels on the floor more uniform and also softens shadows. Brightness on the ceiling appears fairly uniform, ranging from 17 cd/m$^2$ to 82 cd/m$^2$.

Four high-bay storage shelves are currently in use, creating one full-height aisle. The lighting has been coordinated with the shelf layout so that luminaires are centered directly above the 6’ (1.8 m) aisle. Vertical illuminances are relatively uniform (less than 8 to 1 maximum to minimum) over the height of the shelves, making it easy for forklift operators to see the package labels on the lower shelves. Illuminances on the floor of the aisle are 15 to 21 fc (160 to 230 lx). In areas of the warehouse without tall shelving, they range from 32 to 37 fc (340 to 398 lx).

**Shipping and Receiving**

In this area, workers retrieve an order of finished CDs from the warehouse, assemble it into boxes or pallets, and load it onto trucks through one of 12 loading bays. Raw materials for manufacturing are also received here. Visual tasks include reading package labels, filling out paperwork for dispatching, using computers to track orders, and loading materials in and out of trucks.

The ceiling height is 20’ (6.1 m). Economical T8 fluorescent direct/indirect pendants (type AA) are suspended 16’ (4.9 m) above the floor in rows 10’ (3 m) on center. Light from the luminaires reflects off white-painted ceiling, trusses, and walls to produce very uniform illuminances. Floor illuminances range from 31 fc (330 lx) near the loading doors to 43 fc (460 lx) in the center of the space. The luminaires emit much of their light upward, and the ceiling brightness created by the uplight helps make the space appear large and bright. Ceiling luminances of 54 to 96 cd/m$^2$ help reduce the contrast between the luminaires and surrounding ceiling. The luminaires have opaque metal sides and downlight louvers with a 45° cutoff angle, dramatically reducing the sensation of glare.

Swivel-head dock lights (type DD) with incandescent PAR lamps are wall-mounted at each loading bay to aim light into truck cavities. The extendable arm projects light into the truck, which illuminates the area where the worker is headed. However, as soon as the worker walks into the beam of light, his or her body shadows the task area. Workers also complain of “extreme glare” once they turn around because they are now facing a high-candlepower light source that is very close to their line of sight. As a result, workers in the Shipping and Receiving area report that the lighting for loading and unloading trucks is inadequate and uncomfortable. (See Lessons Learned.)
Energy Impact  
DELTA calculated lighting power densities (LPDs) for both the industrial and the administrative parts of the Sony facility. The total connected LPD in the evaluated industrial spaces is 1.34 W/ft² (14.4 W/m²). The in-use LPD is the same, because all lights are on 24 hours a day. Other spaces in the manufacturing side of the facility include equipment maintenance areas, corridors, mechanical and electrical spaces, engineering and controls offices, and pre-mastering rooms. When these spaces are included in the calculation, the industrial facility’s total LPD is 1.04 W/ft² (11.2 W/m²). These LPDs compare very favorably with the ASHRAE/IES 90.1 1989 whole-building unit lighting power allowance (ULPA) of 2.5 W/ft². The Oregon State Energy Code provides equipment wattages for lighting density calculations, which DELTA used instead of manufacturer’s input wattage data. (Although the Oregon State Energy Code governs the energy use in this facility, the code specifically excludes manufacturing spaces from lighting power density limits.)

Controls  
The EMS allows Sony’s facilities managers to control all lighting circuits in the building from a central point so that they can switch off lighting in areas that are not in use. (The EMS is used extensively in office and other support spaces.) However, manufacturing operations run continuously, so lights are rarely off. The following table summarizes the lighting power density in the industrial areas, compared to ASHRAE/IES energy standards and the Oregon State Energy Code.

### Building Areas and Lighting Power Densities

<table>
<thead>
<tr>
<th>Space</th>
<th>Total area (ft²)</th>
<th>Total connected LPD</th>
<th>ASHRAE/IES Allowed LPD</th>
<th>Oregon State Allowed LPD</th>
<th>In-use LPD during day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Staging &amp; Replication</td>
<td>15,502</td>
<td>1.87</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Packaging</td>
<td>23,491</td>
<td>1.64</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Shipping &amp; Receiving</td>
<td>11,682</td>
<td>0.97</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Warehouse</td>
<td>57,358</td>
<td>1.14</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Other Industrial Areas</td>
<td>119,088</td>
<td>0.77</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td><strong>Total Industrial Area</strong></td>
<td><strong>227,121</strong></td>
<td><strong>1.04</strong></td>
<td><strong>2.5</strong></td>
<td><strong>NA</strong></td>
<td><strong>1.04</strong></td>
</tr>
<tr>
<td>Administrative Area</td>
<td>97,679</td>
<td>1.13</td>
<td>1.57**</td>
<td>1.2</td>
<td>0.95</td>
</tr>
<tr>
<td><strong>Grand Total for Building</strong></td>
<td><strong>324,800</strong></td>
<td><strong>1.07</strong></td>
<td>—</td>
<td>—</td>
<td><strong>1.01</strong></td>
</tr>
</tbody>
</table>

*Oregon State Code excludes manufacturing from lighting energy use requirements.

**From ASHRAE/IES 90.1 1989 Table 6.5 ULPA for offices of 50,000–250,000 ft²

Environmental and Economic Analyses

The lighting design features provided significant energy savings for Sony Disc Manufacturing. DELTA compared the annual energy cost for the industrial side of the building with the annual energy cost for a facility using 2.5 W/ft², the maximum whole-building LPD allowed by ASHRAE/IES 90.1 1989. For this comparison, DELTA assumed all lights are in operation continuously.

The annual cost savings for lighting is $82,500 per year, assuming a $4.80/kW demand charge and a standard industrial energy rate for Springfield customers that averages about $.026/kWh for a load of Sony’s size. The average energy rate is weighted for all quantities used, times of day, and times of year. The building’s mechanical system, which uses an economizer cycle in this mild climate, was designed so that the lighting loads have little effect on HVAC operating costs. As a result, DELTA did not calculate energy savings from reduced use.

According to the United States Environmental Protection Agency’s (EPA) estimates on the reduction of emissions of harmful substances into the atmosphere for reductions in energy use, the energy saved from lighting in the industrial areas results in 2180 fewer tons of CO₂, 19 fewer tons of SO₂, and 8 fewer tons of NOX compounds emitted from power plants per year.

The initial cost of the lighting equipment for the whole building was $150,000 higher than a more conventional design. However, the Springfield Utility Board and the power distributor, Bonneville Power Administration, compensated Sony for much of the difference with a rebate of $102,000 to help defray future energy generation costs in the Pacific Northwest.

Staff Response

The DELTA team surveyed employees in several of the facility’s manufacturing areas to find out about their impressions and experiences with the lighting. DELTA wanted to know about task visibility, visual comfort, problems employees noticed with the lighting or windows, and overall satisfaction with the lighting. Employees from several shifts completed surveys in each of the areas DELTA evaluated. In addition to rating their agreement with a series of statements about the lighting, they checked lighting problems they perceived from a list. In areas with significant daylight contributions, such as the Staging area, they

> “I’ve screen-printed for several years and this is one of the best lighting conditions I’ve worked in.”  
> –Printing operator

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were asked to rate the lighting for both day and night.

About 70% of the employees in the manufacturing areas approved of the electric lighting. Both midnight to noon (A.M.) and noon to midnight (P.M.) shift workers in all areas liked the lighting and found it comfortable. However, technicians who perform exacting visual tasks found the lighting less than satisfactory.

Staging  
More than a third of technicians in the Staging area in A.M. and P.M. shifts reported that the lighting did not enable them to see everything they needed to see clearly and quickly. They said they wanted better lighting to help them with their inspection tasks. The A.M. workers were less satisfied than the P.M. workers. The reason, they commented, was that the early morning daylight from clerestory windows created reflected glare on computer screens and glass walls. A.M. workers also complained about direct glare from the morning sun (57%) and the strong shadows cast by the sun (29%).

Packaging  
In Packaging, visual tasks are less demanding than in the Staging. Replication, or Printing areas. Employees in this area were generally satisfied with the lighting, found it comfortable, and reported that they could see quickly and clearly. The Packaging area has no windows, so employees did not complain about daylighting, but some did report glare from reflections of the overhead lighting in shiny packaging materials such as shrink-wrap plastic. Others complained of annoying glare from light refracted through the edges of their safety glasses, or from electric lighting. Too much light was a problem for 15% of these employees.

Warehouse  
In the Warehouse area, workers were quite satisfied. Light levels were sufficient for driving and using a forklift. The metal halide lamps used in this area drew no complaints about flicker or color, although workers reported glare when they needed to see the top of the warehouse shelves while standing on the aisle floor. From this viewing angle, it is hard to avoid seeing the metal halide lamp directly.

Shipping and Receiving  
Some problems surfaced in Shipping and Receiving, particularly at the loading docks. When employees drive forklifts out of the dark interiors of trucks, they report glare or even “blinding” from the incandescent PAR-lamp task lights that are arm-mounted at the edge of the loading dock. Employees working at loading or unloading trucks find that their own strong shadows interfere with their ability to see objects and labels at the far end of the truck. (See Lessons Learned.)

Maintenance and Product Performance  
Sony’s facilities managers have reported an above-average maintenance performance for the lighting design in the 18 months the facility has been open. No frequent lamp burnouts requiring continued maintenance and very few ballast failures have occurred. Managers are very pleased that the energy-efficient lighting design has kept energy use to a minimum.

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**LIGHTING SURVEY—Percentages of People Who Agree***:

<table>
<thead>
<tr>
<th></th>
<th>Replication &amp; Printing</th>
<th>Staging</th>
<th>Packaging</th>
<th>Warehouse</th>
<th>Shipping &amp; Receiving</th>
</tr>
</thead>
<tbody>
<tr>
<td>I like the lighting of this area</td>
<td>71</td>
<td>77</td>
<td>66</td>
<td>70</td>
<td>67</td>
</tr>
<tr>
<td>The lighting is comfortable</td>
<td>78</td>
<td>73</td>
<td>61</td>
<td>60</td>
<td>67</td>
</tr>
<tr>
<td>The lighting helps me see clearly/quickly</td>
<td>44</td>
<td>63</td>
<td>81</td>
<td>60</td>
<td>67</td>
</tr>
<tr>
<td>Having daylight is important</td>
<td>—</td>
<td>65</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td><strong>Percentages of people who checked as a lighting problem:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Too little light</td>
<td>17</td>
<td>0</td>
<td>7</td>
<td>20</td>
<td>16</td>
</tr>
<tr>
<td>Too much light</td>
<td>10</td>
<td>12</td>
<td>15</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Glare from electric lighting</td>
<td>15</td>
<td>6</td>
<td>30</td>
<td>30</td>
<td>16</td>
</tr>
<tr>
<td>Glare from sunlight</td>
<td>17</td>
<td>25</td>
<td>3</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Shadows</td>
<td>19</td>
<td>19</td>
<td>5</td>
<td>20</td>
<td>16</td>
</tr>
<tr>
<td>Patchy lighting</td>
<td>24</td>
<td>6</td>
<td>5</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Flicker</td>
<td>0</td>
<td>0</td>
<td>8</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Poor light color</td>
<td>5</td>
<td>0</td>
<td>12</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Reflected patterns of light</td>
<td>5</td>
<td>12</td>
<td>3</td>
<td>10</td>
<td>16</td>
</tr>
</tbody>
</table>

*Responses from A.M. and P.M. workers are combined.

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“In Printing, light is not directed to accomplish specific tasks, such as seeing inside autoroll print heads, or visual inspection of printed discs, or to verify matching ink to the color chart.”  
—Technician, Replication and Printing

“This facility is a lot lower maintenance than other manufacturing buildings.”  
—Manager of Facilities Engineering

**Replication and Printing**  
More than half of the technicians in the Replication and Printing area also reported that they could not see everything they needed to see quickly and clearly. Among A.M. workers in the Replication area, 30% reported a problem with glare from sunlight and patchy lighting; 19% of all workers complained of strong shadows. The Printing area technicians reported that the general lighting was not designed for their specific visual tasks, such as identifying problems inside the printing machinery where artwork is stamped onto the silk-screen master, visual inspection of the completed printed discs, and color matching to ensure that printed colors match artwork colors.

**Shipping and Receiving**  
Some problems surfaced in Shipping and Receiving, particularly at the loading docks. When employees drive forklifts out of the dark interiors of trucks, they report glare or even “blinding” from the incandescent PAR-lamp task lights that are arm-mounted at the edge of the loading dock. Employees working at loading or unloading trucks find that their own strong shadows interfere with their ability to see objects and labels at the far end of the truck. (See Lessons Learned.)

**Lessons Learned**

“Lessons Learned” are summaries of insights derived from the lighting survey and feedback from employees. These lessons can be categorized into three main areas: lighting design, employee satisfaction, and productivity. The lessons learned from this facility can help guide future lighting projects in similar environments.

1. Lighting Design: Consider specific lighting needs for different tasks and environments. For example, the Packaging area requires well-focused lighting for visual tasks, while the Warehouse area benefits from more general illumination.

2. Employee Satisfaction: Engage employees in the lighting design process to ensure their input is valued and considered. This can enhance overall satisfaction and productivity.

3. Productivity: Optimize lighting to improve visual tasks, such as verifying artwork on the printing machine and inspecting printed discs in the Printing area. This can lead to increased efficiency and fewer errors.

These lessons learned can be applied to future lighting projects to improve employee satisfaction and productivity.
Lessons Learned

• **Choosing the right computer screen can solve VDT lighting problems.** The surface characteristics of a computer screen affect its visibility. A screen with high luminance (brightness) and a good anti-reflection coating can reduce reflected glare to such an extent that almost any electric lighting system will work well. It is only when poor quality screens are used that design of the lighted environment is critical.

• **Task visibility is not always improved with more light.** In the case of inspecting CDs for irregularities, high ambient light levels did not improve visibility. It is often more economical in terms of equipment and energy to design a special viewing booth which can enhance the visibility of surface or substrate flaws through side lighting, a selective light spectrum, specular reflections, diffuse lighting, or other visual inspection techniques. This viewing booth should be specifically designed for the application and specific features that technicians must detect.

• **Windows can reduce visibility.** Reflections of bright windows can seriously interfere with visibility through interior panels of glass or with visual tasks performed on computer screens. Although employees enjoy the ability to see outdoors, glare-control devices such as blinds or shades should be installed to block the offending light at the time of day or year when direct sun penetrates the space.

“In Shipping and Receiving, the light overall is very good. The only problem is lights on the dock doors.”

—Employee, Shipping and Receiving

• **Uplight on ceilings improves warehouse lighting.** The uplight on white-painted ceilings serves several important functions. It makes the luminaires appear less glaring because it reduces the contrast between the luminaire and its background. It provides soft, bounced light at the task level, which helps wash out distracting shadows. It provides greater vertical illuminance on storage shelves. Finally, it provides a psychological lift because the space appears brighter and more cheerful.

• **Dock lights often create poor seeing conditions.** Traditional dock lights do a poor job of lighting truck cavities because they use a narrow-beam PAR lamp to direct light deep inside the truck. Forklifts, and materials cast very strong shadows that get in the way of the light beam, and the concentrated light causes uncomfortable seeing conditions for workers as they come out of the truck. An improved dock light design would use a lower-brightness lamp and a larger reflector system that provides more diffuse light into the truck.

DELTA MEMBERS

Bonneville Power Administration
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Sony Disc Manufacturing, Springfield, OR

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