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**ABSTRACT**

This report presents the results of a research project which was undertaken at an Oklahoma manufacturing facility from September 1989 through May 1990. This report is serving as a master's project for an M.S. degree in Industrial Engineering and Management at Oklahoma State University, which will be completed in May 1990. This project consists of research and identification of the most current lighting technologies available today which can reduce the lighting energy costs at this manufacturing facility, as well as provide any environmental benefits to it, such as improved aesthetics. Several different lighting alternatives are identified in this report and the most probable ones are selected from this group.

# I. INTRODUCTION

Energy conservation was a very important issue to companies several years ago during the energy crisis, in which energy prices were escalating rapidly. Many companies even started their own energy conservation programs. However, due to the fall of energy prices in many areas of the country during the last several years, such as Oklahoma, the perceived importance of energy conservation has diminished and consequently, many programs have been reduced or eliminated altogether. This action may seem acceptable while prices are low and the need for energy conservation appears to be reduced. However, companies taking this non-conservative attitude are in danger of being in financial jeopardy should another energy crisis arise. Therefore, it is worthwhile for companies to start and maintain good energy conservation programs because they will save these companies money during the "good" economic times, while preparing them to deal adequately with any energy crisis. Lighting is just an example of the many different areas which an energy conservation program can positively affect.

The remainder of this report discusses the results of the research which was done on the possible lighting systems available for the Oklahoma manufacturing facility. It presents the available lighting technologies, the current lighting system, the most probable lighting alternatives, an economic analysis of these alternatives, and the recommended actions to be taken.

## II. AVAILABLE TECHNOLOGIES

This section discusses the current lighting alternatives available in the market today. Many of the new technologies available require completely different lighting systems with all new equipment, while others require some new equipment which can operate with an old system. Due to the primary use of fluorescent lighting at the Oklahoma facility in 4′ foot (F40T12) and 8′ foot (F96T12) applications, only those alternatives which are possible fluorescent replacements for these fixtures and lamps are presented.

A. Energy Efficient Fluorescent Lamps

Energy efficient (EE) fluorescent lamps consume less energy than standard lamps while providing nearly the same light levels. These EE lamps cost more initially, but the incremental cost will be recovered through energy savings. There are basically two types of EE fluorescent lamps:

1). Lamps that do not alter the color rendition and visual definition. Lamps considered within this category are Supersavers and Octron T-8 lamps made by Sylvania.

2). Lamps that have a higher lumen output and an improved color rendition. Lamps considered within this category are the Aurora IV made by VL Service Lighting Corporation and the Advantage X made by North American Philips Lighting Corporation.

B. Solid State (Electronic) Ballasts

Solid state ballasts, also called electronic ballasts, are designed with solid state electronics, whereas the standard, electromagnetic ballasts are designed from a specialized electrical transformer. The solid state ballasts operate on a much higher frequency than standard ballasts, approximately 20,000 Hz., which allows the fluorescent lamps to operate more efficiently, consuming less energy, while providing light levels equal to or greater than those of electromagnetic ballasts. In addition to the consumption savings, solid state ballasts also can provide considerable energy savings through reduced chilling and air conditioning needs, due to the ballasts' cooler operation. Other benefits over standard ballasts include longer lamp life, no lamp flicker, broader range of operation, lighter weight, smaller size, and no audible hum. Solid state ballasts, made by MagneTek Triad and Electronic Ballast Technology, Inc. (EBT), are considered later in the alternatives.

In addition to the savings provided, a major incentive to use solid state ballasts has just recently been created by the U.S. government. A law has been passed that requires all ballast manufacturers to stop manufacturing standard electromagnetic ballasts and begin manufacturing either energy efficient electromagnetic ballasts or electronic ballasts as of January 1, 1990. Specifically, beginning January 1990, no ballast manufacturer can produce any non-energy saving ballasts for the following lamp types: F40T12, F96T12, and

F96T12HO. Due to this law, companies in the U.S. will have to replace their old standard ballasts with some type of energy efficient ballasts whenever new ballasts are needed. Ultimately, this law should increase the demand for electronic ballasts, since they are more efficient than the energy efficient electromagnetic ballasts. Therefore, it is very evident that electronic ballasts are the way of the future.

C. Fluorescent Reflectors

Fluorescent reflectors are devices, having an optical design and a specular finish, which are installed into fluorescent fixtures to direct light out of those fixtures more efficiently. Reflectors are primarily comprised of one of two materials; either various grades of specular aluminum (polished or with anodic coating applied) or silver film laminated to a metallic substrate of aluminum or steel. In addition to the material comprised of, the position of the reflective surfaces, with respect to the lamps, can affect the performance of the fixture. In the proper application, reflectors allow for a decrease in the number of lamps required for a fixture while providing approximately the same light levels. Therefore, reflectors can provide reduced energy consumption as well as reduced air-conditioning loads. Silver film relectors, made by the Silverlight Corporation, are considered as a possible alternative.

D. Metal Halide Lamps

Metal halide lamps are in the category of high-intensity discharge (HID) lamps. Metal halide applications involve the use of a single metal halide lamp with its own fixture and ballast. This light source is most useful in high-ceiling applications where color rendition and white light are required, but task lighting is not. Metal halide lamps are more efficient than fluorescent lamps, thus, providing for energy savings. In addition, they have a longer expected life which can reduce the replacement costs. However, the initial cost of changing to metal halide lamps is quite high due to the high cost of the lamp, the fixture and its ballast, and the installation, which involves the removal of the fluorescent fixtures. Metal halide lamps of 400 Watts each, made by Sylvania and Venture, are possible alternatives.

E. Parabolic Fluorescent Fixtures

Parabolic fluorescent fixtures are fixtures which are much more efficient than standard fluorescent fixtures due to their deep cell construction. The louvers control light coming from optimally contoured cells which reduce the amount of light loss within the fixture and concentrate the light out, where it is needed. These fixtures are so efficient that, in the proper application, the total number of fixtures and lamps required can be reduced. Therefore, energy savings will be realized, not to mention the tremendous impact on the aesthetics or looks of the environment surrounding the lighting system. These parabolic fixtures are perfect for office applications. Parabolic fixtures produced by Metalux Lighting, a division of Cooper Industries, Inc., are considered as a possible alternative.

## III. CURRENT LIGHTING SYSTEM

This section presents the current lighting system at the Oklahoma manufacturing facility. Since the majority of the lighting in this facility is fluorescent, the only areas of concern are those with this lighting source. The major areas of interest are in the office and the plant buildings. The office building is a separate building from the plant building, with the two being connected by an inner breezeway. This office building has four floors in it, with the first three floors having the largest number of fluorescent fixtures. The first three floors have the same basic ceiling lighting arrangement (9′ ceiling), as shown in Figure 1 on page 9.

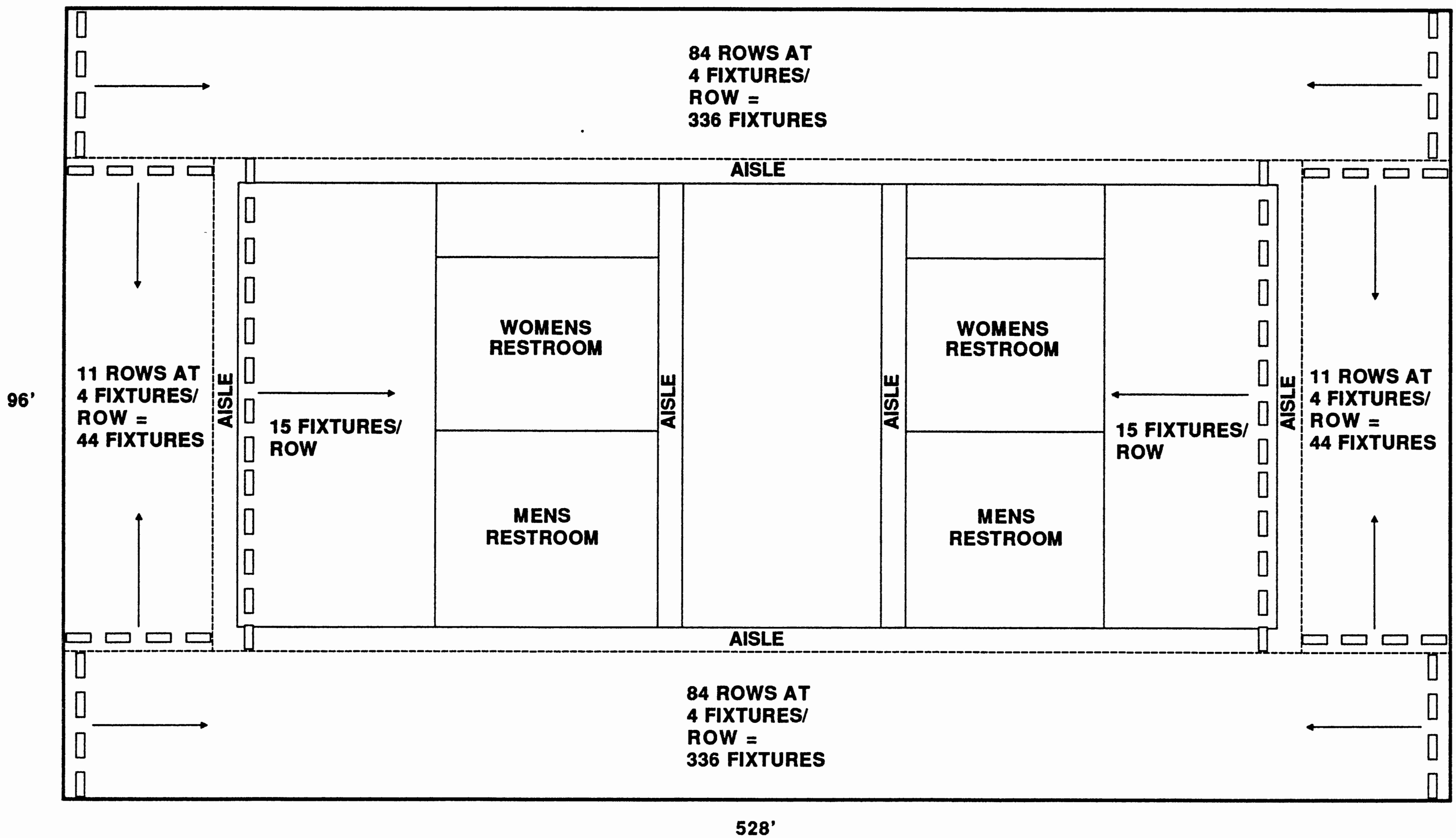
The plant building, on the other hand, has both ceiling lighting for general lighting needs and task or "dropped down" lighting for high activity areas. The area of interest, in this report, is the ceiling lighting which is mounted at 17′. This lighting can be changed without affecting the task lighting arrangements. Figure 2, on page 10, illustrates the plant lighting of concern.

The office building is currently using 1′x4′ two lamp fluorescent fixtures with two 34 watt Sylvania Supersaver fluorescent lamps and one Mark III (2 lamp) electromagnetic ballast. The Sylvania lamps in use are energy efficient lamps, while the Mark III ballasts are energy efficient electromagnetic ballasts. The plant area is using 8′ two lamp slimline fluorescent fixtures equipped with two 60 watt Sylvania Supersaver fluorescent lamps and one Mark III (2 lamp) electromagnetic ballast.

Due to the existing use of energy efficient lamps and ballasts throughout this facility, the possibilities for finding plausible alternatives becomes more difficult, because switching to energy efficient lighting equipment is the easiest and usually the most economical alternative. The data, shown in Table 1 on page 11, presents the lighting equipment currently being used, as well as other important information about this facility, which will be used throughout the remainder of this report.

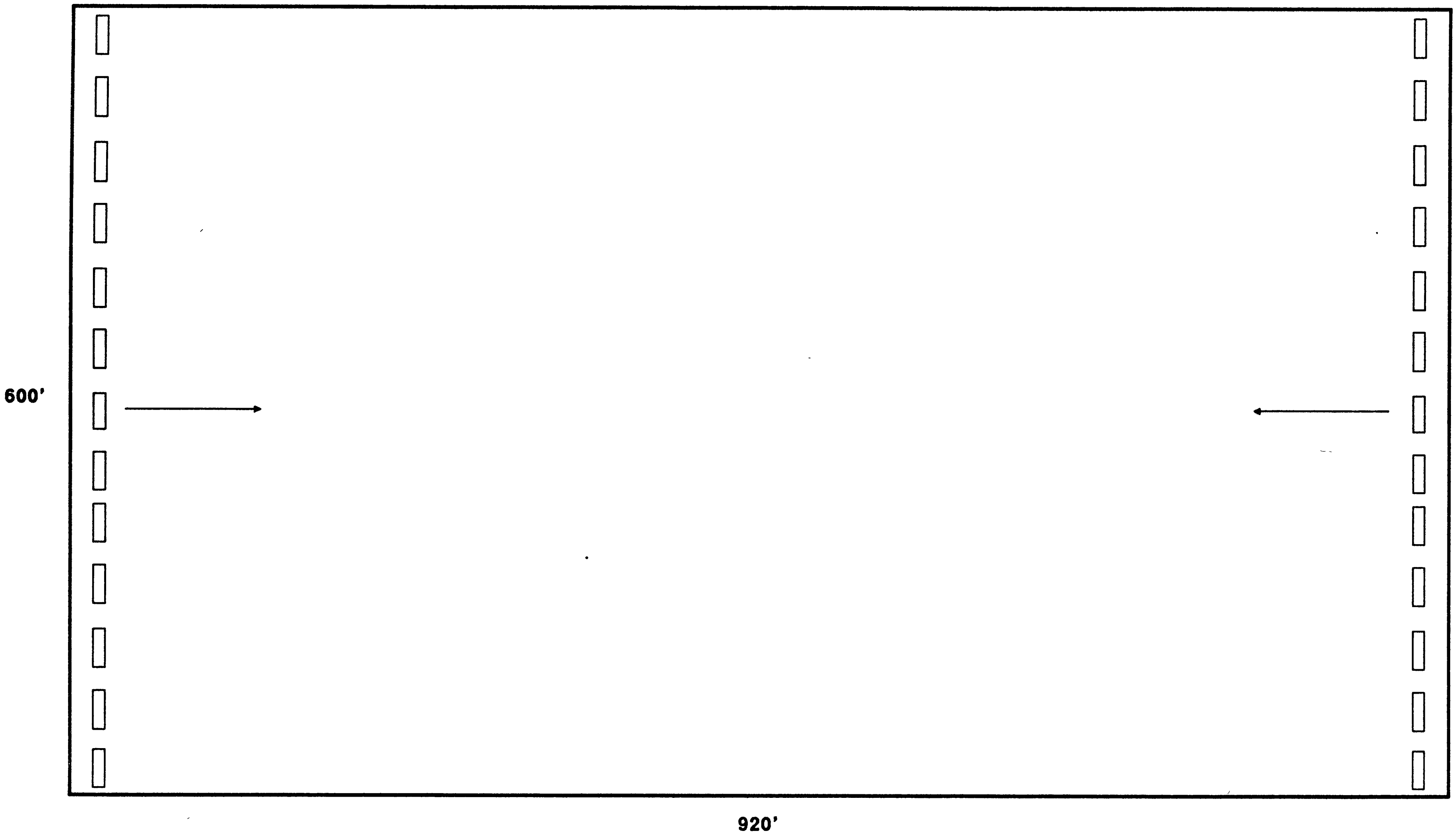
An additional item, which is considered throughout the economic analysis, is the lighting replacement program that the Oklahoma facility currently uses. This program provides for the periodic replacement of all fluorescent lamps, the cleaning of all fixtures, and the replacement of any needed ballasts. The F40T12 fixtures, which are primarily in the office building, are given this service every third year because the F40/LW/SS lamps currently being used have operating lives of 20,000 hours. The F96T12 fixtures, on the other hand, are given this service more frequently because the F96T12/LW/SS lamps being used have operating lives of 12,000 hours. Ballasts for these fixtures are normally replaced as they wear out or during a planned relamping.

# Figure 1: TYPICAL OFFICE BUILDING FLOOR LAYOUT




SMALL RECTANGLES REPRESENT 1'X4' FLUORESCENT FIXTURES
TOTAL NUMBER OF FIXTURES = 1,677 FIXTURES / FLOOR (1st 3 FLOORS)

# Figure 2: PLANT BUILDING LAYOUT




**SMALL RECTANGLES REPRESENT F96 SLIMLINE (8') FLUORESCENT FIXTURES**
**TOTAL NUMBER OF FIXTURES = 7,022 FIXTURES**

Table 1: **CURRENT LIGHTING INFORMATION**

**Yearly Operating Hours:**

OPERATING HOURS/YR = 6,552 (18 HRS/DAY, 7 DAYS/WK, 52 WKS/YR)

**Lighting Equipment Currently In Use:**

OFFICE LIGHTING:
    FIXTURE: 1'X4' (2 LAMP) METALUX P3GAX-240S28H EQUIVALENT
    LAMPS: F40LW/SS 34W RAPID START SUPERSAVER
    BALLAST: MARK III V-2S40-TP (2 LAMP)
PLANT LIGHTING:
    FIXTURE: SLIMLINE (2 LAMP) METALUX STN-296 EQUIVALENT
    LAMPS: F96T12/LW/SS 60W INSTANT START SLIMLINE SUPERSAVER
    BALLAST: MARK III V-2E75-S-TP (2 LAMP)

**Number Of Fixtures:**

OFFICE LIGHTING: # 4' (1'X4') P3GAX-240S28H FIXTURES = 5,372
    AVERAGE NUMBER OF FIXTURES (1ST THREE FLOORS) = 1,677
    TOTAL # 4' (1'X4') P3GAX-240S28H FIXTURES = 6,240
PLANT LIGHTING: # 8' SLIMLINE STN-296 FIXTURES = 7,022
    TOTAL # 8' SLIMLINE STN-296 FIXTURES = 7,224

**Floor Space:**

OFFICE AREAS:
    TOTAL AREA / AVERAGE FLOOR = 50,668 SQ. FT.
    TOTAL AREA FOR ALL FLOORS = 106,904 SQ. FT.
PLANT AREA:
    TOTAL AREA FOR PLANT = 552,000 SQ. FT.

**Labor Rates:**

UNION = $42.58/HOUR
SUB-CONTRACTOR = $25.00/HOUR

**Energy Costs:**

CONSUMPTION CHARGE = $0.02951/kwh (RATE ALTERNATIVES AFFECT)
DEMAND CHARGE = $5.20/MONTH (1989 AVERAGE)
C.O.P. USED = 3.0 (FOR OKLAHOMA)

**Lighting Requirements:**

    FOR OFFICE AREA: LIGHT TO DESKTOP = 3' (9 ' CEILING)
        LIGHT LEVEL RECOMMENDED (MAINTAINED) = 80 FC
    FOR PLANT AREA : DISTANCE TO FLOOR = 17' (17 ' CEILING)
        LIGHT LEVEL RECOMMENDED (MAINTAINED) = 65 FC

**Reflectances (Recommended By Smith Lighting Of OKC):**

    CEILING = 70%
    ALL WALLS = 50%
    FLOOR = 20%

**Lighting Level Factors:**

    COEFFICIENT OF UTILIZATION (CU): FIXT. PHOTOMETRIC TABLE
    LUMEN DIRT DEPRECIATION (LDD):GRAPH

# IV. LIGHTING ALTERNATIVES

This section presents the four most promising lighting alternatives which the manufacturing facility in Oklahoma should consider. After careful analysis, these alternatives have been selected as the most plausible ones to reduce its energy consumption and costs. The first and third alternatives are concerned with the office building only. The second alternative involves both the office and plant buildings, while the fourth alternative considers the plant building only.

## A. Alternative 1

The first alternative looks at the possibilities of using one lamp reflectors in the office building. The office building is currently using 1'X4' two lamp fixtures with 34 watt Supersaver lamps (F40/LW/SS) and Mark III two lamp ballasts (V-2S40-TP). This alternative analyzes the use of one Silverlight reflector per fixture with one Sylvania octron 32 watt lamp (F032/4100K) and a two lamp electronic ballast.

The 32 watt octron lamps were selected as the primary lamps for analysis because of their measured increase in light output over 34 watt lamps (via research done by Oklahoma State's Industrial Engineering Department). In addition to the octron lamp, the Aurora IV lamp made by VL Service Lighting Corporation and the Advantage X lamp made by North American Philips Lighting Corporation are analyzed.

Through the use of two lamp ballasts, each ballast can serve two different one lamp fixtures. Since the octron lamp requires a special ballast, two types of T-8 octron electronic ballasts are considered. One is manufactured by MagneTek Triad, the B232I277 ballast, while the other is manufactured by Electronic Ballast Technologies (EBT), the SSB1-277-2/32 ballast.

B. <u>Alternative 2</u>

The second alternative looks at the possibilities of replacing the current Mark III energy efficient electromagnetic ballasts in both the 4′ and 8′ fluorescent fixtures with electronic ballasts. All of the 4′ and 8′ fixtures throughout the facility are used in this analysis, not just those in the office or plant buildings. On the 4′ fixtures, both two lamp ballasts (one ballast per fixture) and four lamp ballasts (one ballast per two fixtures) are analyzed to see which is more appropriate. On 8′ fixtures, only two lamp ballasts (one ballast per fixture) are considered. MagneTek Triad and EBT ballasts are considered in this analysis. The MagneTek ballasts that are evaluated are the B240R277 (4′ fixture, 2 lamp), the B440R277 (4′ fixture, 4 lamp), and the B275I277 (8′ fixture, 2 lamp) ballast. EBT's ballasts that are evaluated are the SSB1-277-2/40 (4′ fixture, 2 lamp), the SSB2-277-4/32IS (4′ fixture, 4 lamp), and the SSB2-277-2/96IS (8′ fixture, 2 lamp) ballast.

C. <u>Alternative 3</u>

The third alternative looks at replacing the current 1'X4' two lamp fixtures (Metalux P3GAX-240S28H equivalents) in the office building with 2'X4' three lamp parabolic fixtures. The parabolic fixtures evaluated are the 2P3GAX-340S36M fixtures made by Metalux. These fixtures are much more efficient and produce better light levels than standard fixtures, thus, allowing for fewer total lamps. Therefore, they can provide substantial energy savings. Three lamp ballasts are used in these fixtures to provide for reduced ballast costs. Both MagneTek Triad and EBT ballasts are again considered for use in these new fixtures. MagneTek's B440R277 three lamp ballast and EBT's SSB1-277-3/40 three lamp ballast are evaluated.

D. <u>Alternative 4</u>

The fourth alternative looks at replacing the current 8' two lamp slimline fixtures in the plant area with metal halide lamps and fixtures. The plant area is currently using 8' two lamp slimline fixtures (Metalux STN-296 equivalents) equipped with 60 watt Sylvania Supersaver lamps (F96T12/LW/SS) and Mark III two lamp ballasts (V-2E75-S-TP). The alternative is to use a metal halide fixture equipped with a metal halide lamp. Both Sylvania and Venture metal halide products are evaluated as possible alternatives. In addition, several different sizes of lamps are evaluated.

## V. ECONOMIC ANALYSIS OF LIGHTING ALTERNATIVES

This section presents the economic analysis for each of the four lighting alternatives discussed in the previous section. First, a brief description of the economic analysis and its purpose are presented. Next, the economic analysis comparing the four alternatives is discussed and presented through several different tables.

### A. Discussion Of Economic Analysis

The purpose of an economic analysis is to evaluate project alternatives, through a number of different methods, to determine the return on investment for each alternative over a certain period of time. The following economic analysis is presented to help the manufacturing facility recognize and choose the best lighting alternative(s). The analysis consists of comparing the initial costs of the alternatives to their yearly returns.

One method used in this comparison is the payback period, which is simply the number of years that it takes to return the initial investment without considering the time value of money, interest. The payback period should only be used as a comparison figure between the alternatives, not as a decision maker because it fails to take into account the time value of money.

Another method used is the annual worth of each project, which is simply the initial investment and yearly savings annualized into receipts (+) or costs (-) of that project over a given planning horizon, considering the time value of money. The annual worth should be used as the criteria for decision making. If the annual worth is positive or greater that $0, then the alternative should be considered. However, if the annual worth is negative or less than $0, then the alternative should not be considered because its returns are insufficient.

B. Economic Analysis Of Alternatives

Presented in the following pages is the economic analysis for the four lighting alternatives. The interest rate used to consider the time value of money was selected at 21%. This analysis includes several different tables which compare the alternatives. These tables show only the final numbers; however, the actual calculations used to obtain these numbers can be found in Appendices C and D at the end of this report. In addition, Appendix A shows the raw formulas used in these calculations should any questions arise.

**1. PROPOSED LAYOUTS FOR LIGHTING ALTERNATIVES**

For alternatives 1 and 2, the current fixture layouts will not change. Both of these alternatives just require modification of the current lighting fixtures, without changing the positioning or placement of the fixtures. Alternatives 3 and 4, however, use totally different lighting fixtures than those that currently exist, and therefore, require new layouts for the lighting system.

Based on the requirement of a maintained illumination level of 80 footcandles (FC) at desktop heigth in the office building, alternative 3 requires 820 parabolic fixtures per floor. The total number of fixtures required for all four floors is 2,604. The proposed layout is to have 10 rows of 68 fixtures each and 2 rows of 70 fixtures each (the outside rows on each floor). These fixtures will be evenly spaced, placed end-to-end, and positioned parallel with the length of the floor. The calculations and detail of this proposed layout are shown in Appendix B for alternative 3.

Also based on the requirement of a maintained illumination level of 65 footcandles (FC) at the floor in the plant building, alternative 4 requires 1,590 Venture 400 watt metal halide fixtures. Venture lamps are used because they proved to be the most economical of the two selected, as seen from the coming sections. The proposed layout is to have 30 rows of 53 fixtures each positioned parallel with the length of the plant building. These fixtures will be evenly spaced and should provide acceptable levels of light for the plant. The calculations and detail of this proposed layout are shown in Appendix B for alternative 4.

## 2. ENERGY SAVINGS

Lighting alternatives can basically have two purposes. One purpose is to reduce energy consumption, thus, providing for an energy cost savings. The second possible purpose is to simply improve the quality of lighting or the aesthetics of the environment, without saving energy or money. In this situation, a company is simply making a capital investment to improve the lighting system or its looks, while neglecting the concern of financial returns from the new system. For the purpose of this report, lighting alternatives which have the purpose of providing energy savings, while maintaining or even improving lighting quality, are of primary concern.

Energy consumption is measured by the amount of electricity (watts) consumed by an electric device, lighting fixtures in this particular project. Therefore, energy consumption savings are measured by the wattage saved per fixture. It can also be quantified as the percent of original energy consumption saved per fixture. Table 2, on the next page, presents the energy consumption savings for the four alternatives. The calculations for the numbers in this table are in Appendix C at the end of this report.

As seen from Table 2, each of the four alternatives provide energy savings, either through reduced wattage consumed per fixture (alternatives 1 and 2) or reduced wattage required per square foot of area being lit (alternative 3 and 4). Alternative 0 is the do nothing alternative, which represents the current lighting system, both in the office and plant buildings. This alternative is used and presented throughout the economic analysis as a gauge to measure the other four alternatives against.

# Table 2: WATTAGE PER FIXTURE AND PERCENT ENERGY SAVINGS

| ALTERNATIVE | FIXTURE WATTAGE (WATTS) | SAVINGS PER FIXTURE (WATTS) | % ENERGY SAVINGS |
|---|---|---|---|
| 0. DO NOTHING | | | |
| 4' FIXTURES: F40/CW/SS: MARK III BALLAST: V-2S40-TP | 72 | 0 | 0 |
| 8' FIXTURES: F96T12/CW/SS: MARK III BALLAST: V-2E75-S-TP | 123 | 0 | 0 |
| 1. REFLECTORS IN 4' OFFICE FIXTURES WITH 1 OCTRON LAMP | | | |
| MAGNETEK TRIAD (2 LAMP) BALLASTS: B240R277 | 29 | 43 | 59.7 |
| EBT (2 LAMP) BALLASTS: SSB1-277-2/40 | 31 | 41 | 56.9 |
| 2. ELECTRONIC BALLASTS IN 4' & 8' FIXTURES | | | |
| MAGNETEK TRIAD BALLASTS | | | |
| 4': 2 LAMP BALLAST: B240R277 | 61 | 11 | 15.3 |
| 4': 4 LAMP BALLAST: B440R277 | 59 | 13 | 18.1 |
| 8': 2 LAMP BALLAST: B275I277 | 113 | 10 | 8.1 |
| EBT BALLASTS | | | |
| 4': 2 LAMP BALLAST: SSB1-277-2/40 | 57 | 15 | 20.8 |
| 4': 4 LAMP BALLAST: SSB2-277-4/32IS | 54.5 | 17.5 | 24.3 |
| 8': 2 LAMP BALLAST: SSB2-277-2/96IS | 105 | 18 | 14.6 |
| **ALTERNATIVE** | **FIXTURE WATTAGE (WATTS)** | **WATTS SAVED PER SQ. FT.** | |
| 3. PARABOLIC FIXTURES IN OFFICE BUILDING (2'X4': 3 LAMP) | | | |
| MAGNETEK TRIAD BALLASTS | | | |
| 3 LAMP BALLAST: B440R277 | 94 | 0.86 | |
| EBT BALLASTS | | | |
| 3 LAMP BALLAST: SSB1-277-3/40 | 90 | 0.92 | |
| 4. METAL HALIDE LAMPS IN PLANT BUILDING | | | |
| 400 W. SYLVANIA METAL HALIDE: M400/U (36,000 LUMENS) | 460 | 0.09 | |
| 400 W. VENTURE METAL HALIDE: MH400/U (40,000 LUMENS) | 460 | 0.23 | |

## 3. LIGHTING EQUIPMENT COSTS

Equipment costs are the capital expenditures required to obtain the lighting equipment needed for implementation of the alternatives. For each of the four lighting alternatives of concern, the total equipment installation cost consists of lamp costs, ballast costs, fixture costs, and installation labor costs. Lamp and ballast costs are simply the cost of each individual lamp or ballast to be used in an alternative's installation. The total fixture costs are the costs of the fixtures plus any additional hardware, such as reflectors, which will be needed in an alternative's installation. Installation labor costs are the total labor costs for equipment installation for an alternative. These installation costs are calculated using both union labor and subcontractor labor. All of the equipment costs for the four alternatives are shown in Table 3 on the next page. A good comparison between the alternatives is to look at the last column of Table 3, which shows the total cost per fixture for all possible equipment combinations for an alternative.

# Table 3: EQUIPMENT COSTS FOR LIGHTING ALTERNATIVES

| ALTERNATIVE | LAMP COST ($ / UNIT) | BALLAST COST ($ / UNIT) | FIXTURE COST ($ / UNIT) | INSTALLATION COST UNION LABOR ($ / FIXT.) | INSTALLATION COST SUBCONT LABOR ($ / FIXT.) | TOTAL INSTALLED COST ($/FIX) SUBCONT. LAB. |
|---|---|---|---|---|---|---|
| 0. DO NOTHING | | | | | | |
| 4' FIXTURES: F40/CW/SS: MARK III BALLAST: V-2S40-TP | 1.13 | 7.31 | N/A | N/A | N/A | 9.57 |
| 8' FIXTURES: F96T12/CW/SS: MARK III BALLAST: V-2E75-S-TP | 2.38 | 12.25 | N/A | N/A | N/A | 17.01 |
| 1. REFLECTORS IN 4' OFFICE FIXTURES WITH 1OCTRON LAMP | | | REFLECTOR | | | |
| MAGNETEK TRIAD (2 LAMP) BALLAST: B232I277 | 3.67 | 34.52 | 19.00 | 19.60 | 11.67 | 68.86 |
| EBT (2 LAMP) BALLAST: SSB1-277-2/32 | 3.67 | 21.00 | 19.00 | 19.60 | 11.67 | 55.34 |
| 2. ELECTRONIC BALLASTS IN 4' & 8' FIXTURES | | | | | | |
| MAGNETEK TRIAD BALLASTS | | | | | | |
| 4': 2 LAMP BALLAST: B240R277 | N/A | 26.95 | N/A | 7.10 | 4.17 | 31.12 |
| 4': 4 LAMP BALLAST: B440R277 | N/A | 39.92 | N/A | 8.87 | 5.21 | 45.13 |
| 8': 2 LAMP BALLAST: B275I277 | N/A | 35.51 | N/A | 7.10 | 4.17 | 39.68 |
| EBT BALLASTS | | | | | | |
| 4': 2 LAMP BALLAST: SSB1-277-2/40 | N/A | 20.00 | N/A | 7.10 | 4.17 | 24.17 |
| 4': 4 LAMP BALLAST: SSB2-277-4/32IS | N/A | 25.00 | N/A | 8.87 | 5.21 | 30.21 |
| 8': 2 LAMP BALLAST: SSB2-277-2/96IS | N/A | 27.00 | N/A | 7.10 | 4.17 | 31.17 |
| 3. PARABOLIC FIXTURES IN OFFICE BUILDING (2'X4': 3 LAMP) | | | | | | |
| MAGNETEK TRIAD BALLASTS | | | FIXTURE | | | |
| 3 LAMP BALLAST: B440R277 | 1.13 | 39.92 | 56.66 | 42.58 | 25.00 | 124.97 |
| EBT BALLASTS | | | | | | |
| 3 LAMP BALLAST: SSB1-277-3/40 | 1.13 | 24.00 | 56.66 | 42.58 | 25.00 | 109.05 |
| 4. METAL HALIDE LAMPS IN PLANT BUILDING | | | FIXTURE | | | |
| 400 W. SYLVANIA METAL HALIDE: M400/U (36,000 LUMENS) | 29.39 | N/A | 85.00 | 127.74 | 75.00 | 189.39 |
| 400 W. VENTURE METAL HALIDE: MH400/U (40,000 LUMENS) | 26.35 | N/A | 85.00 | 127.74 | 75.00 | 186.35 |

## 4. ECONOMIC SUMMARY

The following economic summary presents the most pertinent economic decision making information which should be used in evaluating the four lighting alternatives. It takes into account the initial capital investment required and the yearly savings provided and then uses the payback period and the annual worth to evaluate each alternative. As mentioned earlier, the annual worth should be used as the criteria for economic decision making. Table 4 and Table 5, on the next two pages, present the economic summary of the four alternatives using subcontractor and union labor, respectively.

The initial investment is the total equipment cost for each alternative. It is based on the price per fixture from Table 3 and the number of fixtures being used.

The yearly savings is the total dollar savings provided per year by each alternative. This yearly savings includes consumption savings, demand savings, air conditioning savings, and replacement savings. Consumption savings were just discussed in part 2 above. Demand savings, on the other hand, are the savings provided by a utility company due to a reduction in the energy demand required by the operating company, during the utility's peak demand hours. Air conditioning savings are energy savings from reduced air conditioning loads that are provided by lighting fixtures which operate cooler, giving off less operating heat. Replacement savings are savings realized from the reduced material and labor costs required to replace lamps and ballasts for an alternative in comparison with the old system.

The payback periods and the annual worths are straightforward numbers, derived from formulas in Appendix A. The calculations for all of the table numbers are shown in Appendix C.

As seen from both Table 4 and Table 5, alternative 1 seems to be the most favorable alternative because of the small payback periods and the annual worth values. In addition, alternative 2 looks favorable when the right combination of EBT ballasts are used (4 lamp ballasts in 4′ fixtures and 2 lamp ballasts in 8′ fixtures). Alternatives 3 and 4, however, show unfavorably long payback periods and negative annual worths. Therefore, the implementation of these alternatives does not look very plausible at this time, based on the information in Table 4 and Table 5.

# Table 4: ECONOMIC SUMMARY (SUBCONTRACTOR LABOR)

| ALTERNATIVE | INITIAL INVESTMENT ($) | YEARLY SAVINGS ($) | PAYBACK PERIOD (YEARS) | ANNUAL WORTH ($) |
|---|---|---|---|---|
| 1. REFLECTORS IN 4' OFFICE FIXTURES WITH 1 OCTRON LAMP | | | | |
| MAGNETEK TRIAD (2 LAMP) BALLAST: B232I277 | 277,195 | 73,966 | 3.7 | 12,207 |
| EBT (2 LAMP) BALLAST: SSB1-277-2/32 | 240,340 | 70,524 | 3.4 | 16,976 |
| 2. ELECTRONIC BALLASTS IN 4' & 8' FIXTURES | | | | |
| MAGNETEK TRIAD BALLASTS | | | | |
| 2 LAMP BALLASTS: 4' B240R277, 8' B275I277 | 481,414 | 45,181 | 10.7 | -62,078 |
| 4 LAMP BALL.: 4' B440R277, 2 LAMP BALL.: 8' B275I277 | 444,178 | 48,255 | 9.2 | -50,708 |
| EBT BALLASTS | | | | |
| 2 LAMP BALLASTS: 4' SSB1-277-2/40, 8' SSB2-277-2/96IS | 376,431 | 71,701 | 5.3 | -12,168 |
| 4 LAMP: 4' SSB2-277-4/32IS, 2 LAMP: 8' SSB2-277-2/96IS | 305,902 | 76,712 | 4 | 8,557 |
| 3. PARABOLIC FIXTURES IN OFFICE BUILDING (2'X4': 3 LAMP) | | | | |
| MAGNETEK TRIAD BALLASTS | | | | |
| 3 LAMP BALLAST: B440R277 | 604,097 | 44,310 | 13.6 | -90,283 |
| EBT BALLASTS | | | | |
| 3 LAMP BALLAST: SSB1-277-3/40 | 562,641 | 47,400 | 11.9 | -77,956 |
| 4. METAL HALIDE LAMPS IN PLANT BUILDING | | | | |
| 400 W. SYLVANIA METAL HALIDE: M400/U (36,000 LUMENS) | 324,303 | 16,934 | 19.2 | -55,321 |
| 400 W. VENTURE METAL HALIDE: MH400/U (40,000 LUMENS) | 286,151 | 44,348 | 6.4 | -19,406 |

# Table 5: ECONOMIC SUMMARY (UNION LABOR)

| ALTERNATIVE | INITIAL INVESTMENT ($) | YEARLY SAVINGS ($) | PAYBACK PERIOD (YEARS) | ANNUAL WORTH ($) |
|---|---|---|---|---|
| 1. REFLECTORS IN 4' OFFICE FIXTURES WITH 1 OCTRON LAMP | | | | |
| MAGNETEK TRIAD (2 LAMP) BALLAST: B232I277 | 321,228 | 73,966 | 4.3 | 2,396 |
| EBT (2 LAMP) BALLAST: SSB1-277-2/32 | 284,913 | 70,524 | 4 | 7,045 |
| 2. ELECTRONIC BALLASTS IN 4' & 8' FIXTURES | | | | |
| MAGNETEK TRIAD BALLASTS | | | | |
| 2 LAMP BALLASTS: 4' B240R277, 8' B275I277 | 520,922 | 45,181 | 11.5 | -70,880 |
| 4 LAMP BALL.: 4' B440R277, 2 LAMP BALL.: 8' B275I277 | 488,271 | 48,255 | 10.1 | -60,532 |
| EBT BALLASTS | | | | |
| 2 LAMP BALLASTS: 4' SSB1-277-2/40, 8' SSB2-277-2/96IS | 415,939 | 71,701 | 5.8 | -20,970 |
| 4 LAMP: 4' SSB2-277-4/32IS, 2 LAMP: 8' SSB2-277-2/96IS | 328,829 | 76,712 | 4.3 | 3,449 |
| 3. PARABOLIC FIXTURES IN OFFICE BUILDING (2'X4': 3 LAMP) | | | | |
| MAGNETEK TRIAD BALLASTS | | | | |
| 3 LAMP BALLAST: B440R277 | 771,639 | 44,310 | 17.4 | -127,611 |
| EBT BALLASTS | | | | |
| 3 LAMP BALLAST: SSB1-277-3/40 | 730,183 | 47,400 | 15.4 | -115,285 |
| 4. METAL HALIDE LAMPS IN PLANT BUILDING | | | | |
| 400 W. SYLVANIA METAL HALIDE: M400/U (36,000 LUMENS) | 410,370 | 16,934 | 24.2 | -74,496 |
| 400 W. VENTURE METAL HALIDE: MH400/U (40,000 LUMENS) | 362,866 | 44,348 | 8.2 | -36,499 |

## 5. ILLUMINATION LEVELS

In addition to the economic considerations, the choice of a particular lighting alternative depends on the lighting or illumination level provided by the alternative. Lighting illumination level is measured in footcandles (FC), which is the illumination on a surface one square foot in area on which there is a uniformly distributed flux of one lumen. In simple terms, the illumination level describes how much light is distributed to a particular area. However, determining lighting illumination levels is often not an easy task.

The easiest method to use is simply to measure the light level, or FCs, at a specific height by using a light meter. However, the use of a light meter is limited to existing lighting systems or an experimental environment created for the system being analyzed. Due to time constraints on this project, an experiment was not setup to evaluate the four alternatives using a light meter.

Therefore, the illumination levels provided by these alternatives had to be calculated. This calculation becomes rather complicated because so many factors must be considered. The calculation of initial FCs provided requires the consideration of the coefficient of utilization (CU), which involves the efficiency of the fixture to put out light. The CU values used come from fixture photometric tables. In addition, lumen dirt depreciation (LDD), which involves how much the illumination levels will diminish due to environmental conditions, such as dirt, must be considered.

The LDD also considers the light reflectance abilities of the ceiling, the walls, and the floor surrounding the light fixture. The LDD factor is determined with a graph through a calculated room cavity ratio (RCR).

For average FCs maintained, the calculation requires the above two factors as well as the lamp lumen depreciation (LLD) factor. LLD involves the depreciation of the lamp over time, due to normal operating conditions. The illumination levels provided by the four alternatives are illustrated in Table 6 on the next page. The calculations for the numbers in this table are shown in Appendix D.

# Table 6: ILLUMINATION LEVELS PROVIDED BY ALTERNATIVES

| ALTERNATIVE | INITIAL ILLUMINATION (FC) | AVERAGE ILLUMINATION (FC) | MEASURED ILLUMINATION (FC) |
|---|---|---|---|
| 0. DO NOTHING | | REQUIREMENT: | |
| OFFICE BUILDING 4' FIXTURES (AT DESKTOP) | | 80 | 75 |
| PLANT BUILDING 8' FIXTURES (AT DESKTOP) | | 65 | 65 |
| 1. REFLECTORS IN 4' OFFICE FIXTURES WITH 1 OCTRON LAMP | | | |
| MAGNETEK TRIAD (2 LAMP) BALLAST: B232I277 | 70.1 | 56.1 | N/A |
| EBT (2 LAMP) BALLAST: SSB1-277-2/32 | 70.1 | 56.1 | N/A |
| 2. ELECTRONIC BALLASTS IN 4' & 8' FIXTURES | | | |
| MAGNETEK TRIAD BALLASTS | | | |
| 2 LAMP BALLASTS: 4' B240R277, 8' B275I277 | N/A | N/A | N/A |
| 4 LAMP BALL.: 4' B440R277, 2 LAMP BALL.: 8' B275I277 | N/A | N/A | N/A |
| EBT BALLASTS | | | |
| 2 LAMP BALLASTS: 4' SSB1-277-2/40, 8' SSB2-277-2/96IS | N/A | N/A | N/A |
| 4 LAMP: 4' SSB2-277-4/32IS, 2 LAMP: 8' SSB2-277-2/96IS | N/A | N/A | N/A |
| 3. PARABOLIC FIXTURES IN OFFICE BUILDING (2'X4': 3 LAMP) | | | |
| MAGNETEK TRIAD BALLASTS | | | |
| 3 LAMP BALLAST: B440R277 | 100 | 80.1 | N/A |
| EBT BALLASTS | | | |
| 3 LAMP BALLAST: SSB1-277-3/40 | 100 | 80.1 | N/A |
| 4. METAL HALIDE LAMPS IN PLANT BUILDING | | | |
| 400 W. SYLVANIA METAL HALIDE: M400/U (36,000 LUMENS) | 81.2 | 65 | N/A |
| 400 W. VENTURE METAL HALIDE: MH400/U (40,000 LUMENS) | 81.3 | 65 | N/A |

# VI. RECOMMENDATION

This section discusses the best recommendation for the Oklahoma manufacturing facility, based on the economic analysis presented in the previous section. A great deal of information can be gathered from the analysis of each of the four alternatives. Therefore, that information is first used to create a table summarizing the pros and cons of each alternative. Next, a table is shown which presents the two most important decision making criteria provided by each alternative, the annual worth and the illumination level. Based on these two tables, a recommendation can be formulated.

## A. Pros & Cons Of Each Alternative

From the economic analysis presented in the previous section, the four alternatives can be evaluated objectively by their advantages and disadvantages in implementation. These pros and cons are presented in Table 7 on the next page.

## B. Decision Making Criteria Summary

As mentioned several times before, the annual worth and the light illumination level provided by each alternative are the two primary decision making criteria. The annual worth gives a true picture of each alternative's financial returns over time because it considers the time value of money. On the other hand, a lighting alternative is not worthwhile if it does not provide sufficient light levels, despite how good its financial returns are. Therefore, Table 8, on page 31, is presented to show the true expected performance of each alternative over time (using subcontractor labor).

# Table 7: PROS AND CONS OF ALTERNATIVES

| ALTERNATIVE | PROS | CONS |
|---|---|---|
| 1. REFLECTORS IN 4' OFFICE FIXTURES WITH 1 OCTRON LAMP<br>MAGNETEK TRIAD (2 LAMP) BALLAST: B232I277<br>EBT (2 LAMP) BALLAST: SSB1-277-2/32 | 1. CONSIDERABLE ENERGY AND DOLLAR SAVINGS.<br>2. ACCEPTABLE PROJECT USING MAGNETEK OR EBT BALLASTS USING THE AW CRITERIA. | 1. HIGH INITIAL INVESTMENT.<br>2. ILLUMINATION LEVEL PROVIDED IS TOO LOW. |
| 2. ELECTRONIC BALLASTS IN 4' & 8' FIXTURES<br>MAGNETEK TRIAD BALLASTS<br>2 LAMP BALLASTS: 4' B240R277, 8' B275I277<br>4 LAMP BALL.: 4' B440R277, 2 LAMP BALL.: 8' B275I277<br>EBT BALLASTS<br>2 LAMP BALLASTS: 4' SSB1-277-2/40, 8' SSB2-277-2/96IS<br>4 LAMP: 4' SSB2-277-4/32IS, 2 LAMP: 8' SSB2-277-2/96IS | 1. GOOD ENERGY AND DOLLAR SAVINGS.<br>2. ACCEPTABLE PROJECT USING EBT BALLASTS AND AW(21%).<br>3. THE 4' FIXTURE 4 LAMP EBT BALLAST CAN BE WIRED PARALLEL; IF 1 LAMP BURNS OUT, THE OTHER 3 DO NOT.<br>4. LIGHT LEVELS DO NOT DECREASE, MAY INCREASE DUE TO BALLAST EFFICIENCY.<br>5. MEETS THE NEW BALLAST LAW. | 1. BALLASTS ARE EXPENSIVE; HIGH INITIAL INVESTMENT. |
| 3. PARABOLIC FIXTURES IN OFFICE BUILDING (2'X4': 3 LAMP)<br>MAGNETEK TRIAD BALLASTS<br>3 LAMP BALLAST: B440R277<br>EBT BALLASTS<br>3 LAMP BALLAST: SSB1-277-3/40 | 1. WILL IMPROVE AESTHETICS OR LOOKS OF THE OFFICE AREA.<br>2. WILL INCREASE THE LIGHT LEVEL FROM CURRENT LEVELS.<br>3. WILL REDUCE THE LABOR LOAD OF REPLACING LAMPS AND BALLASTS. | 1. HIGH INITIAL INVESTMENT.<br>2. REQUIRES NEW CEILINGS IN THE OFFICE BUILDING.<br>3. DOES NOT PAYBACK USING AW(21%). |
| 4. METAL HALIDE LAMPS IN PLANT BUILDING<br>400 W. SYLVANIA METAL HALIDE: M400/U (36,000 LUMENS)<br>400 W. VENTURE METAL HALIDE: MH400/U (40,000 LUMENS) | 1. WILL REDUCE THE LABOR LOAD OF LAMP REPLACEMENT AND CLEANING CONSIDERABLY.<br>2. LIGHT LEVELS IN THE PLANT WILL NOT DECREASE. | 1. HIGH INITIAL INVESTMENT.<br>2. REQUIRES THE REMOVAL OF FLUORESCENT FIXTURES AND REWIRING OF NEW METAL HALIDE FIXTURES.<br>3. DOES NOT PAYBACK USING AW(21%). |

# Table 8: SUMMARY OF DECISION MAKING CRITERIA

| ALTERNATIVE | ANNUAL WORTH ($) | INITIAL ILLUMINATION (FC) | AVERAGE ILLUMINATION (FC) |
|---|---|---|---|
| 1. REFLECTORS IN 4' OFFICE FIXTURES WITH 1 OCTRON LAMP | | | |
| MAGNETEK TRIAD (2 LAMP) BALLAST: B232I277 | 12,207 | 70.1 | 56.1 |
| EBT (2 LAMP) BALLAST: SSB1-277-2/32 | 16,976 | 70.1 | 56.1 |
| 2. ELECTRONIC BALLASTS IN 4' & 8' FIXTURES | | | |
| MAGNETEK TRIAD BALLASTS | | | |
| 2 LAMP BALLASTS: 4' B240R277, 8' B275I277 | -62,078 | N/A | N/A |
| 4 LAMP BALL.: 4' B440R277, 2 LAMP BALL.: 8' B275I277 | -50,708 | N/A | N/A |
| EBT BALLASTS | | | |
| 2 LAMP BALLASTS: 4' SSB1-277-2/40, 8' SSB2-277-2/96IS | -12,168 | N/A | N/A |
| 4 LAMP: 4' SSB2-277-4/32IS, 2 LAMP: 8' SSB2-277-2/96IS | 8,557 | N/A | N/A |
| 3. PARABOLIC FIXTURES IN OFFICE BUILDING (2'X4': 3 LAMP) | | | |
| MAGNETEK TRIAD BALLASTS | | | |
| 3 LAMP BALLAST: B440R277 | -90,283 | 100 | 80.1 |
| EBT BALLASTS | | | |
| 3 LAMP BALLAST: SSB1-277-3/40 | -77,956 | 100 | 80.1 |
| 4. METAL HALIDE LAMPS IN PLANT BUILDING | | | |
| 400 W. SYLVANIA METAL HALIDE: M400/U (36,000 LUMENS) | -55,321 | 81.2 | 65 |
| 400 W. VENTURE METAL HALIDE: MH400/U (40,000 LUMENS) | -19,406 | 81.3 | 65 |

C. <u>Recommendation</u>

Based on the data presented in Table 8, on the previous page, the following conclusions can be made. Alternative 1 provides considerable energy dollar savings for both types of ballasts because the AW is greater than $0 for both subcontractor and union labor, but it fails to provide sufficient light levels. For analysis purposes, two other lamps were analyzed to see if they would provide enough light in the office area.

The Aurora IV lamp made by VL Service Lighting Corporation was one analyzed. This lamp provides 3450 initial lumens and using the same Silverlight reflector proposed, provides 83.4 initial footcandles and 66.8 maintained footcandles.

The Advantage X lamp made by Philips Lighting Company was another lamp analyzed. This lamp provides 3700 initial lumens and using the same reflector proposed, provides 89.5 initial footcandles and 71.6 maintained footcandles.

Although these two lamps provide better light levels, they still do not provide sufficient light levels to warrant the acceptance of alternative 1. Therefore, alternative 1 is not recommended.

Alternative 2 fails to provide sufficient energy dollar savings using any of the ballasts, except for using the EBT ballasts SSB2-277-4/32IS and SSB2-277-2/96IS. The light levels should remain the same as they currently are, if not increasing, due to the better efficiency of these electronic ballasts. Therefore, this alternative is recommended using the particular ballasts just mentioned.

Alternative 3 fails to provide enough energy dollar savings using either subcontractor labor or union labor, but it provides sufficient light levels. However, light level is not enough, therefore, it is not recommended.

Alternative 4 also fails to provide sufficient energy dollar savings using subcontractor labor or union labor, while providing adequate light levels. Therefore, it is also not recommended.

A summary of the above recommendations is presented in Table 9 on the next page. This table provides a clearer picture of the recommended actions that this facility should now take.

# Table 9: SUMMARY OF RECOMMENDATIONS

| ALTERNATIVE | RECOMMENDATION |
|---|---|
| 1. REFLECTORS IN 4' OFFICE FIXTURES WITH 1 OCTRON LAMP | |
| MAGNETEK TRIAD (2 LAMP) BALLAST: B232I277 | NOT RECOMMENDED |
| EBT (2 LAMP) BALLAST: SSB1-277-2/32 | NOT RECOMMENDED |
| | |
| 2. ELECTRONIC BALLASTS IN 4' & 8' FIXTURES | |
| MAGNETEK TRIAD BALLASTS | |
| 2 LAMP BALLASTS: 4' B240R277, 8' B275I277 | NOT RECOMMENDED |
| 4 LAMP BALL.: 4' B440R277, 2 LAMP BALL.: 8' B275I277 | NOT RECOMMENDED |
| EBT BALLASTS | |
| 2 LAMP BALLASTS: 4' SSB1-277-2/40, 8' SSB2-277-2/96IS | NOT RECOMMENDED |
| 4 LAMP: 4' SSB2-277-4/32IS, 2 LAMP: 8' SSB2-277-2/96IS | RECOMMENDED |
| | |
| 3. PARABOLIC FIXTURES IN OFFICE BUILDING (2'X4': 3 LAMP) | |
| MAGNETEK TRIAD BALLASTS | |
| 3 LAMP BALLAST: B440R277 | NOT RECOMMENDED |
| EBT BALLASTS | |
| 3 LAMP BALLAST: SSB1-277-3/40 | NOT RECOMMENDED |
| | |
| 4. METAL HALIDE LAMPS IN PLANT BUILDING | |
| 400 W. SYLVANIA METAL HALIDE: M400/U (36,000 LUMENS) | NOT RECOMMENDED |
| 400 W. VENTURE METAL HALIDE: MH400/U (40,000 LUMENS) | NOT RECOMMENDED |

# VII. CONCLUSION

Lighting is just one operational area which can be affected positively by an energy conservation program. Since the office and plant buildings at the Oklahoma manufacturing facility primarily use fluorescent lighting, that source of lighting was the focus. As presented in the report, many different alternatives exist today for reducing the energy costs of fluorescent lighting. This equipment includes energy efficient lamps and ballasts, fixture reflectors, efficient fluorescent fixtures (parabolics), and high intensity discharge (HID) fixtures, such as metal halide, for high ceiling applications.

This report primarily focused on showing the economic analysis of four fluorescent lighting alternatives that were chosen as possibilities for the manufacturing facility. The annual worths and illumination levels provided by these alternatives were the primary decision making criteria. After careful analysis, the alternative which replaces the existing ballasts with EBT electronic ballasts was the only acceptable alternative. The other alternatives failed to provide sufficient returns on investment and / or adequate light levels.

Even though this project failed to provide many acceptable alternatives, it has provided a great deal of information about energy efficient lighting systems. One of the major reasons that the economic analyses failed to show acceptable alternatives is the fact that the Oklahoma facility pays a very minimal price for electricity. This price has a great deal to do with how much energy dollar savings a lighting alternative can provide. Just because an alternative saves a large amount of energy does not mean that its investment will pay off, especially, when energy charges are low. Therefore, this project could become much more attractive if this electricity rate increased sometime in the future. It could be used at this facility at a later date or even at other manufacturing facilities which pay higher prices for their electricity.

This report has provided important information about the possible benefits from an effective energy conservation program. These types of programs are not only a benefit, but are a necessity in today's business environments. Energy conservation programs can better prepare companies for energy crises, not to mention increasing their competitiveness through reduced overhead expenses.

## VIII. REFERENCES

1. Advance Transformer Co.
   2950 No. Western Ave.
   Chicago, IL. 60618
   (312) 267-8100

2. Burrus & Matthews, Inc.
   1330 Classen Blvd.
   Oklahoma City, OK.
   (405) 232-0011

3. Electronic Ballast Technology, Inc. (EBT)
   2522 W. 237th Street
   Torrance, CA. 90505
   (213) 534-1717

4. GE Lighting
   Nela Park
   Cleveland, OH. 44112
   (216) 266-2121

5. HMI Energy Controls, Inc.
   108 South Chickasaw St.
   Pauls Valley, OK. 73075
   (405) 238-7741

6. Hunzicker Brothers, Inc.
   Box 25248, 501 N. Virginia
   Oklahoma City, OK. 73125
   (405) 239-7771

7. Light Bulb Supply Co., Inc.
   629 W. Hefner
   Oklahoma City, OK. 73114
   (405) 840-2852

8. MagneTek Triad
   1124 E. Franklin Street
   Huntington, IN. 46750
   (219) 356-7100

9. Metalux
   P.O. Box 1207
   Americus, Georgia 31709
   (912) 924-8000

10. Oklahoma State University
   Industrial Engineering Department
   Stillwater, OK. 74074
   (405) 744-6055

11. Philips Lighting Company
200 Franklin Square Drive
P.O. Box 6800
Somerset, NJ. 08875-6800
(201) 563-3000

12. Silverlight Corporation
16 W. 151 Shore Court
Burridge, IL. 60521
(312) 986-1651

13. Smith Lighting Sales, Inc.
4307 N. Walnut
Oklahoma City, OK. 73105
(405) 521-0093

14. Sylvania U.S. Lighting
Sylvania Lighting Center
Danvers, MASS. 01923

15. Venture Lighting International
Cleveland, OH.

16. Voss Electric Supply Co.
1001 Enterprise Ave. No. 3
Oklahoma City, OK. 73128
(405) 949-1919

17. White, John A., Marvin H. Agee, & Kenneth E. Case.
Principles of Engineering Economic Analysis, 2nd Ed.,
Wiley, New York, 1984.

# IX. APPENDICES

A. FORMULAS USED

B. PROPOSED LAYOUTS FOR LIGHTING ALTERNATIVES

C. ECONOMIC ANALYSES FOR THE ALTERNATIVES

D. ILLUMINATION LEVELS PROVIDED BY THE ALTERNATIVES

# APPENDIX A

## FORMULAS USED

**FORMULAS USED**

1). kw SAVINGS = (kw SAVINGS / FIXTURE) x (# FIXTURES)

2). kwh SAVINGS = (kw SAVINGS) x (6552 OPERATING HOURS/YEAR)

3). kwh $ SAVINGS = (kwh SAVINGS) x ($/kwh PAID)

4). DEMAND $ SAVINGS = (kw SAVINGS)*(AVG. DEMAND CHARGE)

5). A/C $ SAVINGS = (kwh SAVINGS/C.O.P.) x ($/kwh PAID)

6). TOTAL YEARLY SAVINGS = #3 + #4 + #5 ABOVE

7). PAYBACK PERIOD = (TOTAL INSTALLATION COST) /
(TOTAL YEARLY SAVINGS)

8). INITIAL LUMENS/SQ.FT. = (TOTAL # LAMPS IN AREA) x
(LUMENS/LAMP) / (AREA IN SQ.FT.)

9). AVERAGE LUMENS/SQ.FT. = (TOTAL # LAMPS IN AREA) x
(LUMENS/LAMP)x(LAMP LUMEN DEPREC.)
/ (AREA IN SQ.FT.)

10). CURRENT WATTS/SQ.FT. = (TOTAL # FIXTURES) x
(TOTAL WATTS/FIXT) /
(AREA IN SQ.FT.)

11). AREA / FIXTURE = (TOTAL AREA IN SQ.FT.) /
(TOTAL # FIXTURES)

12). FOOTCANDLES INITIAL (FCI) = (# LAMPS) x (LUMENS/LAMP) x
(CU) x (MF)/ (AREA IN SQ.FT.)

13). FOOTCANDLES MAINTAINED (FCM) = (# LAMPS) x (LUMENS/LAMP)
x (CU) x (MF) x (LLD)
/ (AREA IN SQ.FT.)

14). MOUNTING HEIGTH =WORK PLANE - HEIGHT OF ROOM CAVITY (HRC)

15). ROOM CAVITY RATIO (RCR) = 5 x (HRC) x (LENGTH + WIDTH) /
(AREA IN SQ.FT.)

16). LAMP LUMEN DEPRECIATION (LLD) = (INITIAL LAMP LUMENS) /
(LAMP LUMENS AT AVG LIFE)

17). N = FIXTURE QUANTITY REQ'D = (FCM) x (AREA IN SQ.FT.) /
(LAMP LUMENS/FIXT) x (CU) x (MF)

18). L (NEW) = SPACE BETWEEN FIXTURES (LENGTHWISE)
= (AREA/FIXTURE)**.5

19). SPACE TO MOUNTING HEIGTH RATIO = (SPACE BETWEEN FIXTURES) / (FIXTURE MOUNTING HEIGTH)

20). ANNUAL WORTH (AW) = (-INITIAL INVESTMENT) x (INTEREST FACTOR) + YEARLY SAVINGS

# APPENDIX B

## PROPOSED LAYOUTS OF LIGHTING ALTERNATIVES

# ALTERNATIVE 3: USING PARABOLIC FIXTURES IN OFFICE BUILDING

**DETERMINATION OF THE NUMBER OF PARABOLIC FIXTURES REQUIRED:**

PARABOLIC FIXTURE TO USE: METALUX 2P3GAX-340S36M 3 LAMP FIXTURE

**USING FORMULAS PRESENTED IN APPENDIX A:**

ILLUMINATION LEVELS REQUIRED AT DESKTOP IN OFFICE AREAS:

FC (INITIAL) = 100 FC
FC (MAINTAINED) = 80 FC

FROM TABLES FOR PARABOLIC FIXTURE (METALUX), CU = 0.83

$$RCR = \frac{(5)(9\text{-}3 \text{ FEET})(528 + 96 \text{ FEET})}{(528)(96) \text{ SQUARE FEET}} = 0.37$$

USING RCR = 0.37, THE MAINTENANCE FACTOR (MF) = 0.85

$$\text{LAMP LUMEN DEPRECIATION (LLD)} = \frac{\text{2340 LUMENS AT AVERAGE LIFE}}{\text{2925 INITIAL LUMENS}} = 0.8$$

N = THE NUMBER OF PARABOLIC FIXTURES REQUIRED PER FLOOR

$$N = \frac{(80 \text{ FC})(528\text{X}96 \text{ SQUARE FEET})}{(2925 \text{ LUMENS/LAMP})(3 \text{ LAMPS/FIXTURE})(0.83)(0.85)(0.80)} = 819 \text{ FIXTURES}$$

**FOR SYMMETRY, USE N = 820 FIXTURES / FLOOR**

USE 820 FIXTURES FOR FIRST 3 FLOORS IN OFFICE BUILDING
USE 144 FIXTURES FOR FOURTH FLOOR (BASED ON THE TYPICAL FLOOR ANALYSIS)

**TOTAL NUMBER OF FIXTURES REQUIRED IN OFFICE BUILDING = 3(820) + 144 = 2,604 FIXTURES**

INITIAL ILLUMINATION LEVEL PROVIDED:

$$\text{FC (INITIAL)} = \frac{(2925 \text{ LUMENS/LAMP})(3 \text{ LAMPS/FIXTURE})(820 \text{ FIXTURES/FLOOR})(0.83)(0.85)}{(528)(96) \text{ SQUARE FEET}}$$

$$= 100.1 \text{ FC}$$

# ALTERNATIVE 3: USING PARABOLIC FIXTURES IN OFFICE BUILDING

**PROPOSED LAYOUT OF PARABOLIC FIXTURES:**

FROM THE PREVIOUS PAGE, THE NUMBER OF FIXTURES REQUIRED / FLOOR = 820

**USING FORMULAS PRESENTED IN APPENDIX A:**

AREA / FIXTURE = $\frac{\text{(528)(96) SQUARE FEET}}{\text{820 FIXTURES}}$ = 61.81 SQUARE FEET / FIXTURE

L (NEW) = THE MAXIMUM SPACE BETWEEN FIXTURES LENGTHWISE

L (NEW) = (61.81 SQUARE FEET / FIXTURE)**0.5 = 7.86 FEET

MINIMUM NUMBER OF FIXTURES IN LENGTH = $\frac{\text{528 FEET}}{\text{7.86 FEET / FIXTURE}}$ = 67.18 FIXTURES

MAXIMUM NUMBER OF FIXTURES IN WIDTH = $\frac{\text{820 FIXTURES/FLOOR}}{\text{67.18 FIXTURES IN LENGTH}}$ = 12.21 FIXTURES

USING THE INFORMATION GATHERED FROM ABOVE, THE FOLLOWING DESIGN APPLIES:
THE FIXTURES ARE LINED UP END TO END, PARALLEL TO THE LENGTH OF THE FLOOR

THE DESIGN CONSTRAINT IS 68 REQUIRED FIXTURES IN LENGTH:

NUMBER OF FIXTURES IN LENGTH FOR THE 10 MIDDLE ROWS ON THE FLOOR = 68 FIXTURES

NUMBER OF FIXTURES IN LENGTH FOR THE 2 OUTSIDE ROWS ON THE FLOOR = 70 FIXTURES

**TOTAL NUMBER OF FIXTURES = (68)(10) + (70)(2) = 820 FIXTURES**

SPACE BETWEEN FIXTURES LENGTHWISE = $\frac{\text{528 FEET LENGTH}}{\text{69 SPACES}}$ = 7.65 FEET

SPACE TO MOUNTING HEIGTH RATIO = $\frac{\text{7.65 FEET BETWEEN FIXT.}}{\text{9 FOOT CEILING}}$ = 0.86

SINCE 0.86 IS LESS THAN 1.0, THIS DESIGN IS ACCEPTABLE.

# ALTERNATIVE 4: USING METAL HALIDE FIXTURES IN PLANT BUILDING

**DETERMINATION OF THE NUMBER OF METAL HALIDE FIXTURES REQUIRED (FOR VENTURE FIXTURES ONLY):**

VENTURE 400 WATT M.H. FIXTURES ARE THE MOST LIKELY ONES TO BE USED; THEREFORE, THE PROPOSED LAYOUT USES THEM.

**USING FORMULAS PRESENTED IN APPENDIX A:**

ILLUMINATION LEVELS REQUIRED AT THE FLOOR IN THE PLANT:

FC (INITIAL) = 80 FC
FC (MAINTAINED) = 65 FC

FROM TABLES FOR VENTURE METAL HALIDE FIXTURE, CU = 0.85

$$RCR = \frac{(5)(17\text{ FEET})(920 + 600\text{ FEET})}{(920)(600)\text{ SQUARE FEET}} = 0.23$$

USING RCR = 0.23, THE MAINTENANCE FACTOR (MF) = 0.83

$$\text{LAMP LUMEN DEPRECIATION (LLD)} = \frac{32{,}000\text{ LUMENS AT AVERAGE LIFE}}{40{,}000\text{ INITIAL LUMENS}} = 0.8$$

N = THE NUMBER OF METAL HALIDE FIXTURES REQUIRED

$$N = \frac{(65\text{ FC})(920\text{X}600\text{ SQUARE FEET})}{(40{,}000\text{ LUMENS/LAMP})(1\text{ LAMP/FIXTURE})(0.85)(0.83)(0.80)} = 1590\text{ FIXTURES}$$

**USE 1,590 FIXTURES IN PLANT AREA SPECIFIED**

INITIAL ILLUMINATION LEVEL PROVIDED:

$$\text{FC (INITIAL)} = \frac{(40{,}000\text{ LUMENS/LAMP})(1\text{ LAMP/FIXTURE})(1590\text{ FIXTURES})(0.85)(0.83)}{(920)(600)\text{ SQUARE FEET}}$$

$$= 81.3\text{ FC}$$

# ALTERNATIVE 4: USING METAL HALIDE FIXTURES IN PLANT BUILDING

**PROPOSED LAYOUT OF METAL HALIDE FIXTURES:**

FROM THE PREVIOUS PAGE, THE NUMBER OF FIXTURES REQUIRED = 1590

**USING FORMULAS PRESENTED IN APPENDIX A:**

$$\text{AREA / FIXTURE} = \frac{(920)(600)\ \text{SQUARE FEET}}{1590\ \text{FIXTURES}} = 347.17\ \text{SQUARE FEET / FIXTURE}$$

L (NEW) = THE MAXIMUM SPACE BETWEEN FIXTURES LENGTHWISE

L (NEW) = (347.17 SQUARE FEET / FIXTURE)**0.5 = 18.63 FEET

$$\text{MINIMUM NUMBER OF FIXTURES IN LENGTH} = \frac{920\ \text{FEET}}{18.63\ \text{FEET / FIXTURE}} = 49.38\ \text{FIXTURES}$$

$$\text{MAXIMUM NUMBER OF FIXTURES IN WIDTH} = \frac{1590\ \text{FIXTURES/FLOOR}}{49.38\ \text{FIXTURES IN LENGTH}} = 32.20\ \text{FIXTURES}$$

USING THE INFORMATION GATHERED FROM ABOVE, THE FOLLOWING DESIGN APPLIES:

THE DESIGN CONSTRAINT IS 50 REQUIRED FIXTURES IN LENGTH:

NUMBER OF FIXTURES IN LENGTH = 53 FIXTURES

NUMBER OF ROWS OF 53 FIXTURES REQUIRED = 30 ROWS

**TOTAL NUMBER OF FIXTURES = (53)(30) = 1590 FIXTURES**

$$\text{SPACE BETWEEN FIXTURES LENGTHWISE} = \frac{920\ \text{FEET LENGTH}}{54\ \text{SPACES}} = 17\ \text{FEET}$$

$$\text{SPACE TO MOUNTING HEIGTH RATIO (LENGTHWISE)} = \frac{17\ \text{FEET BETWEEN FIXT.}}{17\ \text{FOOT CEILING}} = 1$$

$$\text{SPACE BETWEEN FIXTURES WIDTHWISE} = \frac{600\ \text{FEET LENGTH}}{31\ \text{SPACES}} = 19.35\ \text{FEET}$$

$$\text{SPACE TO MOUNTING HEIGTH RATIO (WIDTHWISE)} = \frac{19.35\ \text{FEET BETWEEN FIXT.}}{17\ \text{FOOT CEILING}} = 1.14$$

THE RATIO FOR THE LENGTH DIRECTION IS ACCEPTABLE WHILE THE RATIO FOR THE WIDTH DIRECTION IS BARELY ACCEPTABLE. HOWEVER, THIS DESIGN SHOULD PROVIDE ACCEPTABLE LEVELS OF LIGHT FOR THE PLANT.

# APPENDIX C

# ECONOMIC ANALYSIS OF ALTERNATIVES

# ALTERNATIVE 1: USING MAGNETEK TRIAD BALLASTS

## LIGHTING EQUIPMENT COSTS:

| EQUIPMENT | UNIT COST ($) | VENDOR | QTY. REQUIRED | | | |
|---|---|---|---|---|---|---|
| 1. F032/4100K OCTRON LAMP | 3.67 | SYLVANIA | 5,372 | | | |
| 2. MAGNETEK TRIAD BALLAST B232I277 | 34.52 | MAGNETEK TRIAD | 5,372 | | | |
| 3. SILVERLIGHT REFLECTOR | 19.00 | SILVERLIGHT CORPORATION | 5,372 | | | |

## ENERGY SAVINGS:

| CURRENT INPUT WATTS | PROPOSED INPUT WATTS | WATTS SAVED / FIXTURE | % ENERGY SAVINGS | | | |
|---|---|---|---|---|---|---|
| 72 W / FIXTURE | 58 W / 2 FIXTURES | 43 | 59.7 | | | |

## ENERGY DOLLAR SAVINGS:

| FIXTURE | TOTAL KW SAVINGS | TOTAL KWH SAVINGS | TOTAL KWH $ SAVINGS / YR | TOTAL DEMAND SAVINGS ($) / YR | TOTAL A/C SAVINGS ($) / YR | TOTAL YEARLY SAVINGS ($) |
|---|---|---|---|---|---|---|
| 4' - P3GAX-240S28H EQUIVALENT | 231 | 1,513,512 | 44,664 | 14,414 | 14,888 | 73,966 |

## INSTALLATION COST:

| LABOR USED | TOTAL LAMP COST ($) | TOTAL FIXTURE COST ($) | TOTAL BALLAST COST ($) | TOTAL LABOR COST ($) * | TOTAL COST OF INSTALLATION ($) | PAYBACK PERIOD (YEARS) |
|---|---|---|---|---|---|---|
| SUBCONTRACTOR | 19,715 | 102,068 | 92,721 | 62,691 | 277,195 | 3.7 |
| UNION | 19,715 | 102,068 | 92,721 | 106,724 | 321,228 | 4.3 |

## ANNUAL WORTH (AW) ANALYSIS:

| | | |
|---|---|---|
| SUBCONTRACTOR LABOR: | AW(21%) = -$277,195(.2228) + $73,966 = $12,207 | (A/P 21,15) = 0.2228 |
| UNION LABOR: | AW(21%) = -$321,228(.2228) + $73,966 = $2,396 | |

* TIME TO INSTALL REFLECTORS = 10 MINUTES / REFLECTOR (FROM HMI)

COST TO CHANGE BALLAST, CLEAN FIXTURE, & RELAMP = $7.50 / FIXTURE (SUBCONTRACTOR LABOR)

(RATES FROM LAST RELAMPING) = $12.77 / FIXTURE (UNION LABOR)

# ALTERNATIVE 1: USING EBT BALLASTS

## LIGHTING EQUIPMENT COSTS:

| EQUIPMENT | UNIT COST ($) | VENDOR | QTY. REQUIRED | | | |
|---|---|---|---|---|---|---|
| 1. F032/4100K OCTRON LAMP | 3.67 | SYLVANIA | 5,372 | | | |
| 2. EBT BALLAST SSB1-277-2/32 | 21.00 | EBT, INC. | 5,372 | | | |
| 3. SILVERLIGHT REFLECTOR | 19.00 | SILVERLIGHT CORPORATION | 5,372 | | | |

## ENERGY SAVINGS:

| CURRENT INPUT WATTS | PROPOSED INPUT WATTS | WATTS SAVED / FIXTURE | % ENERGY SAVINGS | | | |
|---|---|---|---|---|---|---|
| 72 W / FIXTURE | 62 W / 2 FIXTURES | 41 | 56.9 | | | |

## ENERGY DOLLAR SAVINGS:

| FIXTURE | TOTAL KW SAVINGS | TOTAL KWH SAVINGS | TOTAL KWH $ SAVINGS / YR | TOTAL DEMAND SAVINGS ($) / YR | TOTAL A/C SAVINGS ($) / YR | TOTAL YEARLY SAVINGS ($) |
|---|---|---|---|---|---|---|
| 4' - P3GAX-240S28H EQUIVALENT | 220.25 | 1,443,078 | 42,585 | 13,744 | 14,195 | 70,524 |

## INSTALLATION COST:

| LABOR USED | TOTAL LAMP COST ($) | TOTAL FIXTURE COST ($) | TOTAL BALLAST COST ($) | TOTAL LABOR COST ($) * | TOTAL COST OF INSTALLATION ($) | PAYBACK PERIOD (YEARS) |
|---|---|---|---|---|---|---|
| SUBCONTRACTOR | 19,715 | 102,068 | 56,406 | 62,691 | 240,340 | 3.4 |
| UNION | 19,715 | 102,068 | 56,406 | 106,724 | 284,913 | 4 |

## ANNUAL WORTH (AW) ANALYSIS:

| | | |
|---|---|---|
| SUBCONTRACTOR LABOR: | AW(21%) = -$240,340(.2228) + $70,524 = $16,976 | (A/P 21,15) = 0.2228 |
| UNION LABOR: | AW(21%) = -$284,913(.2228) + $70,524 = $7,045 | |

* TIME TO INSTALL REFLECTORS = 10 MINUTES / REFLECTOR (FROM HMI)
COST TO CHANGE BALLAST, CLEAN FIXTURE, & RELAMP = $7.50 / FIXTURE (SUBCONTRACTOR LABOR)
(RATES FROM LAST RELAMPING) = $12.77 / FIXTURE (UNION LABOR)

# ALTERNATIVE 2: USING MAGNETEK TRIAD BALLASTS

## LIGHTING EQUIPMENT COSTS:

| EQUIPMENT | UNIT COST ($) | VENDOR | QTY. REQUIRED | | | |
|---|---|---|---|---|---|---|
| 4': 2 LAMP BALLAST- B240R277 | 26.95 | MAGNETEK TRIAD | 6,260 | | | |
| 4': 4 LAMP BALLAST- B440R277 | 39.92 | MAGNETEK TRIAD | 6,260 | | | |
| 8': 2 LAMP BALLAST- B275I277 | 35.51 | MAGNETEK TRIAD | 7,224 | | | |

## ENERGY SAVINGS:

| FIXTURE | CURRENT INPUT WATTS | PROPOSED INPUT WATTS | WATTS SAVED / FIXTURE | % ENERGY SAVINGS | | |
|---|---|---|---|---|---|---|
| 4': 2 LAMP BALLAST | 72 W / FIXTURE | 61 W / FIXTURE | 11 | 15.3 | | |
| 4': 4 LAMP BALLAST | 144 W / 2 FIXTURES | 118 W / 2 FIXTURE | 13 | 18.1 | | |
| 8': 2 LAMP BALLAST | 123 W / FIXTURE | 113 W / FIXTURE | 10 | 8.1 | | |

## ENERGY DOLLAR SAVINGS:

| FIXTURE | TOTAL KW SAVINGS | TOTAL KWH SAVINGS | TOTAL KWH $ SAVINGS / YR | TOTAL DEMAND SAVINGS ($) / YR | TOTAL A/C SAVINGS ($) / YR | TOTAL YEARLY SAVINGS ($) |
|---|---|---|---|---|---|---|
| 4': 2 LAMP BALLAST | 68.86 | 451,171 | 13,314 | 4,297 | 4,438 | 22,049 |
| 4': 4 LAMP BALLAST | 81.38 | 509,439 | 15,034 | 5,078 | 5,011 | 25,123 |
| 8': 2 LAMP BALLAST | 72.24 | 473,316 | 13,968 | 4,508 | 4,656 | 23,132 |

## INSTALLATION COST:

| LABOR USED | TOTAL LAMP COST ($) | TOTAL FIXTURE COST ($) | TOTAL BALLAST COST ($) | TOTAL LABOR COST ($) * | TOTAL COST OF INSTALLATION ($) | PAYBACK PERIOD (YEARS) |
|---|---|---|---|---|---|---|
| SUBCONTRACTOR: | | | | | | |
| 4' & 8': 2 LAMP BALL. | N/A | N/A | 425,231 | 56,183 | 481,414 | 10.7 |
| 4' 4 LAMP, 8' 2 LAMP | N/A | N/A | 381,474 | 62,704 | 444,178 | 9.2 |
| UNION: | | | | | | |
| 4' & 8': 2 LAMP BALL. | N/A | N/A | 425,231 | 95,691 | 520,922 | 11.5 |
| 4' 4 LAMP, 8' 2 LAMP | N/A | N/A | 381,474 | 106,797 | 488,271 | 10.1 |

## ANNUAL WORTH (AW) ANALYSIS:

| | | |
|---|---|---|
| SUBCONTRACTOR LABOR: | 2 LAMP BALLASTS: AW(21%) = -$481,414(.2228) + $45,181 = -$62,078<br>4' 4 LAMP, 8' 2 LAMP BALL.: AW(21%) = -$444,178(.2228) + $48,255 = -$50,708 | (A/P 21,15) = 0.2228 |
| UNION LABOR: | 2 LAMP BALLASTS: AW(21%) = -$520,922(.2228) + $45,181 = -$70,880<br>4' 4 LAMP, 8' 2 LAMP BALL.: AW(21%) = -$488,271(.2228) + $48,255 = -$60,532 | |

* BALLAST REPLACEMENT TIME: 2 LAMP BALLAST = 10 MIN. / FIXTURE, 4 LAMP BALLAST = 25 MIN. / 2 FIXTURES (FROM EBT)

# ALTERNATIVE 2: USING EBT BALLASTS

| LIGHTING EQUIPMENT COSTS: | | | | | | |
|---|---|---|---|---|---|---|
| EQUIPMENT | UNIT COST ($) | VENDOR | QTY. REQUIRED | | | |
| 4': 2 LAMP BALLAST- SSB1-277-2/40 | 20.00 | EBT, INC. | 6,260 | | | |
| 4': 4 LAMP BALLAST- SSB2-277-4/32IS | 25.00 | EBT, INC. | 6,260 | | | |
| 8': 2 LAMP BALLAST- SSB2-277-2/96IS | 27.00 | EBT, INC. | 7,224 | | | |
| **ENERGY SAVINGS:** | | | | | | |
| FIXTURE | CURRENT INPUT WATTS | PROPOSED INPUT WATTS | WATTS SAVED / FIXTURE | % ENERGY SAVINGS | | |
| 4': 2 LAMP BALLAST | 72 W / FIXTURE | 57 W / FIXTURE | 15 | 20.8 | | |
| 4': 4 LAMP BALLAST | 144 W / 2 FIXTURES | 109 W / 2 FIXTURE | 17.5 | 24.3 | | |
| 8': 2 LAMP BALLAST | 123 W / FIXTURE | 105 W / FIXTURE | 18 | 14.6 | | |
| **ENERGY DOLLAR SAVINGS:** | | | | | | |
| FIXTURE | TOTAL KW SAVINGS | TOTAL KWH SAVINGS | TOTAL KWH $ SAVINGS / YR | TOTAL DEMAND SAVINGS ($) / YR | TOTAL A/C SAVINGS ($) / YR | TOTAL YEARLY SAVINGS ($) |
| 4': 2 LAMP BALLAST | 93.90 | 615,233 | 18,155 | 5,859 | 6,052 | 30,066 |
| 4': 4 LAMP BALLAST | 109.55 | 717,772 | 21,181 | 6,836 | 7,060 | 35,077 |
| 8': 2 LAMP BALLAST | 130.03 | 851,957 | 25,141 | 8,114 | 8,380 | 41,635 |
| **INSTALLATION COST:** | | | | | | |
| LABOR USED | TOTAL LAMP COST ($) | TOTAL FIXTURE COST ($) | TOTAL BALLAST COST ($) | TOTAL LABOR COST ($) * | TOTAL COST OF INSTALLATION ($) | PAYBACK PERIOD (YEARS) |
| SUBCONTRACTOR: | | | | | | |
| 4' & 8': 2 LAMP BALL. | N/A | N/A | 320,248 | 56,183 | 376,431 | 5.3 |
| 4' 4 LAMP, 8' 2 LAMP | N/A | N/A | 273,298 | 32,604 | 305,902 | 4 |
| UNION: | | | | | | |
| 4' & 8': 2 LAMP BALL. | N/A | N/A | 320,248 | 95,691 | 415,939 | 5.8 |
| 4' 4 LAMP, 8' 2 LAMP | N/A | N/A | 273,298 | 55,531 | 328,829 | 4.3 |
| **ANNUAL WORTH (AW) ANALYSIS:** | | | | | | |
| SUBCONTRACTOR LABOR: | | 2 LAMP BALLASTS: AW(21%) = -$376,431(.2228) + $71,701 = -$12,168<br>4' 4 LAMP, 8' 2 LAMP BALL.: AW(21%) = -$305,902(.2228) + $76,712 = $8,557 | | | | (A/P 21,15) = 0.2228 |
| UNION LABOR: | | 2 LAMP BALLASTS: AW(21%) = -$415,939(.2228) + $71,701 = -$20,970<br>4' 4 LAMP, 8' 2 LAMP BALL.: AW(21%) = -$328,829(.2228) + $76,712 = $3,449 | | | | |
| * BALLAST REPLACEMENT TIME: 2 LAMP BALLAST = 10 MIN. / FIXTURE, 4 LAMP BALLAST = 25 MIN. / 2 FIXTURES (FROM EBT) | | | | | | |

# ALTERNATIVE 3: PARABOLIC FIXTURES USING MAGNETEK TRIAD BALLASTS

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **LIGHTING EQUIPMENT COSTS:** | | | | | | | |
| EQUIPMENT | UNIT COST ($) | VENDOR | QTY. REQUIRED | | | | |
| 1. METALUX PARABOLIC FIXT.: 2P3GAX-340S36M | 56.66 | METALUX | 2,604 | | | | |
| 2. MAGNETEK BALL.: B440R277 | 39.92 | MAGNETEK TRIAD | 2,604 | | | | |
| 3. EQUIP. FIXTURE | 96.58 | | 2,604 | | | | |
| **ENERGY SAVINGS:** | | | | | | | |
| CURRENT WATTS / SQ. FT. | PROPOSED WATTS /SQ. FT. | WATTS SAVED / SQUARE FOOT | % ENERGY SAVINGS | | | | |
| 2.38 | 1.52 | 0.86 | 36.13 | | | | |
| **ENERGY DOLLAR SAVINGS:** | | | | | | | |
| FIXTURE | TOTAL KW SAVINGS | TOTAL KWH SAVINGS | TOTAL KWH $ SAVINGS / YR | TOTAL DEMAND SAVINGS ($)/YR | TOTAL A/C SAVINGS ($)/YR | TOTAL YEARLY SAVINGS ($) | |
| 4' 2P3GAX-340S36M EQUIVALENT | 138.38 | 906,666 | 26,756 | 8,635 | 8,919 | 44,310 | |
| **INSTALLATION COST:** | | | | | | | |
| LABOR USED | TOTAL LAMP COST ($) | TOTAL FIXTURE COST ($) | TOTAL BALLAST COST ($) | TOTAL LABOR COST ($) * | COST OF NEW CEILING ** | TOTAL INSTAL-LATION COST $ | PAYBACK PER. (YRS) |
| SUBCONTRACTOR | 8,828 | 147,543 | 103,952 | 62,142 | 281,582 | 604,097 | 13.6 |
| UNION | 8,828 | 147,543 | 103,952 | 105,838 | 405,478 | 771,639 | 17.4 |
| **ANNUAL WORTH (AW) ANALYSIS:** | | | | | | | |
| SUBCONTRACTOR LABOR: | AW(21%) = -$604,097(.2228) + $44,310 = -$90,283 | | | | | (A/P 21,15) = 0.2228 | |
| UNION LABOR: | AW(21%) = -$771,639(.2228) + $44,310 = -$127,611 | | | | | | |

* TIME TO INSTALL FIXTURES = 1 HOUR / FIXTURE (FROM SMITH LIGHTING), NUMBERS INCLUDE LABOR REPLACEMENT SAVINGS (SEE REP. SAVINGS)
** OFFICE CEILING REPLACEMENT (INCLUDES LABOR & MATERIAL)

SUBCONTRACTOR LABOR RATE = $1.75 / SQUARE FOOT
UNION LABOR RATE = $2.52 / SQUARE FOOT
TOTAL LIGHTING AREA = 160,904 SQUARE FEET

# ALTERNATIVE 3: PARABOLIC FIXTURES USING EBT BALLASTS

## LIGHTING EQUIPMENT COSTS:

| EQUIPMENT | UNIT COST ($) | VENDOR | QTY. REQUIRED | | | | |
|---|---|---|---|---|---|---|---|
| 1. METALUX PARABOLIC FIXT.: 2P3GAX-340S36M | 56.66 | METALUX | 2,604 | | | | |
| 2. EBT BALLAST: SSB1-277-3/40 | 24.00 | EBT, INC. | 2,604 | | | | |
| 3. EQUIP. FIXTURE | 80.66 | | 2,604 | | | | |

## ENERGY SAVINGS:

| CURRENT WATTS / SQ. FT. | PROPOSED WATTS /SQ. FT. | WATTS SAVED / SQUARE FOOT | % ENERGY SAVINGS | | | | |
|---|---|---|---|---|---|---|---|
| 2.38 | 1.46 | 0.92 | 38.66 | | | | |

## ENERGY DOLLAR SAVINGS:

| FIXTURE | TOTAL KW SAVINGS | TOTAL KWH SAVINGS | TOTAL KWH $ SAVINGS / YR | TOTAL DEMAND SAVINGS ($)/YR | TOTAL A/C SAVINGS ($)/YR | TOTAL YEARLY SAVINGS ($) | |
|---|---|---|---|---|---|---|---|
| 4' 2P3GAX-340S36M EQUIVALENT | 148.03 | 969,893 | 28,622 | 9,237 | 9,541 | 47,400 | |

## INSTALLATION COST:

| LABOR USED | TOTAL LAMP COST ($) | TOTAL FIXTURE COST ($) | TOTAL BALLAST COST ($) | TOTAL LABOR COST ($) * | COST OF NEW CEILING ** | TOTAL INSTAL-LATION COST $ | PAYBACK PER. (YRS) |
|---|---|---|---|---|---|---|---|
| SUBCONTRACTOR | 8,828 | 147,543 | 62,496 | 62,142 | 281,582 | 562,641 | 11.9 |
| UNION | 8,828 | 147,543 | 62,496 | 105,838 | 405,478 | 730,183 | 15.4 |

## ANNUAL WORTH (AW) ANALYSIS:

| | | |
|---|---|---|
| SUBCONTRACTOR LABOR: | AW(21%) = -$562,641(.2228) + $47,400 = -$77,956 | (A/P 21,15) = 0.2228 |
| UNION LABOR: | AW(21%) = -$730,183(.2228) + $47,400 = -$115,285 | |

* TIME TO INSTALL FIXTURES = 1 HOUR / FIXTURE (FROM SMITH LIGHTING), NUMBERS INCLUDE REPLACEMENT LABOR SAVINGS (SEE REP. SAVINGS)

** OFFICE CEILING REPLACEMENT (INCLUDES LABOR & MATERIAL)

SUBCONTRACTOR LABOR RATE = $1.75 / SQUARE FOOT

UNION LABOR RATE = $2.52 / SQUARE FOOT

TOTAL LIGHTING AREA = 160,904 SQUARE FEET

# ALTERNATIVE 3: USING PARABOLIC FIXTURES IN OFFICE BUILDING

**DETERMINATION OF REPLACEMENT SAVINGS:**

LAMP AND BALLAST COST REPLACEMENT SAVINGS ARE NEGLIGLE; THEREFORE, THEY ARE NOT INCLUDED.

HOWEVER, REPLACEMENT LABOR SAVINGS ARE WORTH INCLUDING.

FROM THE PROGRAM, LAMPS SHOULD BE REPLACED EVERY 3 YEARS AND
BALLASTS SHOULD BE REPLACED EVERY 15 YEARS (BALLAST LIFE = 15 YEARS).

| INTEREST FACTORS: |
|---|
| (P/F 21, 3) = 0.5645 |
| (P/F 21, 6) = 0.3186 |
| (P/F 21, 9) = 0.1799 |
| (P/F 21,12) = 0.1015 |
| (P/F 21,15) = 0.0573 |
| (A/P 21,15) = 0.2228 |

**REPLACEMENT LABOR SAVINGS:**
**(APPLY TO BOTH MAGNETEK TRIAD AND EBT BALLASTS)**

NUMBER OF FIXTURES SAVED = 2,768 FIXTURES

**SUBCONTRACTOR LABOR:**

LABOR RATES:
1. COST TO REPLACE THE LAMPS AND CLEAN THE FIXTURE = $3.75 / FIXTURE (9 MINUTES / FIXTURE)
2. COST TO REPLACE THE LAMPS & BALLASTS AND CLEAN THE FIXTURE = $7.50 / FIXTURE (18 MINUTES / FIXTURE)

| | | |
|---|---|---|
| LAMP REPLACEMENT LABOR SAVINGS = | (2,768 FIXTURES)($3.75 / FIXTURE) = | $10,380 |
| BALLAST REPLACEMENT LABOR SAVINGS = | (2,768 FIXTURES)($7.50 / FIXTURE) = | $20,760 |

AW(21%) = [10,380(P/F 21,3) + 10,380(P/F 21,6) + 10,380(P/F 21,9) + 10380(P/F 21,12) + 20760(P/F 21,15)] x (A/P 21,15)
= **$2,958 / YEAR**

**UNION LABOR:**

LABOR RATES:
1. COST TO REPLACE THE LAMPS AND CLEAN THE FIXTURE = $6.39 / FIXTURE (9 MINUTES / FIXTURE)
2. COST TO REPLACE THE LAMPS & BALLASTS AND CLEAN THE FIXTURE = $12.77 / FIXTURE (18 MINUTES / FIXTURE)

| | | |
|---|---|---|
| LAMP REPLACEMENT LABOR SAVINGS = | (2,768 FIXTURES)($6.39 / FIXTURE) = | $17,688 |
| BALLAST REPLACEMENT LABOR SAVINGS = | (2,768 FIXTURES)($12.77 / FIXTURE) = | $35,347 |

AW(21%) = [17,688(P/F 21,3) + 17,688(P/F 21,6) + 17,688(P/F 21,9) + 17,688(P/F 21,12) + 35,347(P/F 21,15)] x (A/P 21,15)
= **$5,040 / YEAR**

# ALTERNATIVE 4: USING SYLVANIA METAL HALIDE FIXTURES IN PLANT

| | | | | | | |
|---|---|---|---|---|---|---|
| **LIGHTING EQUIPMENT COSTS:** | | | | | | |
| EQUIPMENT | UNIT COST ($) | VENDOR | QTY. REQUIRED | | | |
| 1. 400 WATT LAMP: M400/U (36,000 LUM. | 29.39 | SYLVANIA | 1,765 | | | |
| 2. 400 WATT METAL HALIDE FIXTURE | 85.00 | METALUX | 1,765 | | | |
| 3. EQUIPPED FIXTURE | 114.39 | | 1,765 | | | |
| **ENERGY SAVINGS:** | | | | | | |
| CURRENT WATTS / SQ. FT. | PROPOSED WATTS /SQ. FT. | WATTS SAVED / SQUARE FOOT | % ENERGY SAVINGS | | | |
| 1.56 | 1.47 | 0.09 | 5.77 | | | |
| **ENERGY DOLLAR SAVINGS:** | | | | | | |
| FIXTURE | TOTAL KW SAVINGS | TOTAL KWH SAVINGS | TOTAL KWH $ SAVINGS / YR | TOTAL DEMAND SAVINGS ($) / YR | TOTAL A/C SAVINGS ($) / YR | TOTAL YEARLY SAVINGS ($) * |
| M400/U 400 WATT | 49.68 | 325,503 | 9,606 | 3,100 | 3,202 | 16,934 |
| **INSTALLATION COST:** | | | | | | |
| LABOR USED | TOTAL LAMP COST ($) | TOTAL FIXTURE COST ($) | TOTAL LABOR COST ($) ** | TOTAL COST OF INSTALLATION ($) | PAYBACK PERIOD (YEARS) | |
| SUBCONTRACTOR | 51,873 | 150,025 | 122,405 | 324,303 | 19.2 | |
| UNION | 51,873 | 150,025 | 208,472 | 410,370 | 24.2 | |
| **ANNUAL WORTH (AW) ANALYSIS:** | | | | | | |
| SUBCONTRACTOR LABOR: | AW(21%) = -$324,303(.2228) + $16,934 = -$55,321 | | | | | (A/P 21,15) = 0.2228 |
| UNION LABOR: | AW(21%) = -$410,370(.2228) + $16,934 = -$74,496 | | | | | |

* NUMBER INCLUDES $1,026 IN REPLACEMENT SAVINGS (SEE REPLACEMENT SAVINGS CALCULATIONS)

** TIME TO INSTALL FIXTURES = 3 HOURS / FIXTURE (INCLUDES TIME TO REMOVE OLD FIXTURES)
NUMBERS INCLUDE REPLACEMENT LABOR SAVINGS (SEE REPLACEMENT SAVINGS CALCULATIONS)

# ALTERNATIVE 4: USING VENTURE METAL HALIDE FIXTURES IN PLANT

## LIGHTING EQUIPMENT COSTS:

| EQUIPMENT | UNIT COST ($) | VENDOR | QTY. REQUIRED | | | |
|---|---|---|---|---|---|---|
| 1. 400 WATT LAMP: MH400/U (40000 LUM | 26.35 | VENTURE | 1,590 | | | |
| 2. 400 WATT METAL HALIDE FIXTURE | 85.00 | METALUX | 1,590 | | | |
| 3. EQUIPPED FIXTURE | 111.35 | | 1,590 | | | |

## ENERGY SAVINGS:

| CURRENT WATTS / SQ. FT. | PROPOSED WATTS /SQ. FT. | WATTS SAVED / SQUARE FOOT | % ENERGY SAVINGS | | | |
|---|---|---|---|---|---|---|
| 1.56 | 1.33 | 0.23 | 14.74 | | | |

## ENERGY DOLLAR SAVINGS:

| FIXTURE | TOTAL KW SAVINGS | TOTAL KWH SAVINGS | TOTAL KWH $ SAVINGS / YR | TOTAL DEMAND SAVINGS ($) / YR | TOTAL A/C SAVINGS ($) /YR | TOTAL YEARLY SAVINGS ($) * |
|---|---|---|---|---|---|---|
| 400 WATT VENTURE | 126.96 | 831,842 | 24,548 | 7,922 | 8,183 | 44,348 |

## INSTALLATION COST:

| LABOR USED | TOTAL LAMP COST ($) | TOTAL FIXTURE COST ($) | TOTAL LABOR COST ($) ** | TOTAL COST OF INSTALLATION ($) | PAYBACK PERIOD (YEARS) | |
|---|---|---|---|---|---|---|
| SUBCONTRACTOR | 41,897 | 135,150 | 109,104 | 286,151 | 6.4 | |
| UNION | 41,897 | 135,150 | 185,819 | 362,866 | 8.2 | |

## ANNUAL WORTH (AW) ANALYSIS:

| | | |
|---|---|---|
| SUBCONTRACTOR LABOR: | AW(21%) = -$286,151(.2228) + $44,348 = -$19,406 | (A/P 21,15) = 0.2228 |
| UNION LABOR: | AW(21%) = -$362,866(.2228) + $44,348 = -$36,499 | |

* NUMBER INLUDES REPLACEMENT SAVINGS (SEE REPLACEMENT SAVINGS CALCULATIONS)

** TIME TO INSTALL FIXTURES = 3 HOURS / FIXTURE (INCLUDES TIME TO REMOVE OLD FIXTURES)
NUMBERS INCLUDE REPLACEMENT LABOR SAVINGS (SEE REPLACEMENT SAVINGS CALCULATIONS)

# ALTERNATIVE 4: USING SYLVANIA METAL HALIDE FIXTURES IN PLANT

**DETERMINATION OF REPLACEMENT SAVINGS (SUBCONTRACTOR LABOR):**

BALLAST COST REPLACEMENT SAVINGS ARE NEGLIGLE; THEREFORE, THEY ARE NOT INCLUDED.

HOWEVER, LAMP REPLACEMENT SAVINGS AND REPLACEMENT LABOR SAVINGS ARE WORTH INCLUDING.

LAMPS SHOULD BE REPLACED AT END OF LIFE SINCE BOTH OF THEM DO NOT HAVE LIVES OF 3 YEARS
BALLASTS SHOULD BE REPLACED EVERY 15 YEARS (BALLAST LIFE = 15 YEARS).
USE A 3 YEAR PLANNING HORIZON FOR AW ANALYSIS (CONSISTENT WITH **REPLACEMENT PROGRAM**)

LABOR RATES:
1. SUBCONTRACTOR COST TO REPLACE THE LAMP AND CLEAN THE FIXTURE = $3.75 / FIXTURE (9 MINUTES / FIXTURE)
2. THE UNION COST TO REPLACE THE LAMP AND CLEAN THE FIXTURE = $6.39 / FIXTURE (9 MINUTES / FIXTURE)

**LAMP COST REPLACEMENT SAVINGS:**
LAMP LIFES: F96T12/LW/SS -> 12,000 HOURS, VENTURE 400W -> 20,000 HOURS

COST TO REPLACE F96T12 LAMPS = (7022 FIXTURES)(2 LAMPS/FIXTURE)($2.38/LAMP) = $33,425
REPLACE. COST = (3 YEARS)/[(12,000 HOURS LIFE/6552 HOURS/YR)] x (33,425) = $54,750

COST TO REPLACE 400W LAMPS = (1,765 M.H. LAMPS)($29.39/LAMP) = $51,873
REPLACE. COST = (3 YEARS)/[(20,000 HOURS LIFE/6552 HOURS/YR)] x (51,873) = $50,981

AW(21%) = (54,750 - 50,981)(A/F 21,3) = **$1,026** (A/F 21,3) = 0.2722

**SUBCONTRACTOR LABOR SAVINGS:**

LABOR COST OF F96T12 = (7022 FIXTURES)($3.75/FIXTURE)(3 YEARS)/[(12,000 HR LIFE/6552 HOURS/YR)] = $43,133
LABOR COST OF 400W LAMP = (1765 FIXTURES)($3.75/FIXTURE)(3 YEARS)/[(20,000 HR LIFE/6552 HOURS/YR)] = $6,505

AW(21%) = (43,133 - 6,505)(A/F 21,3) = **$9,970**

**UNION LABOR SAVINGS:**

LABOR COST OF F96T12 = (7022 FIXTURES)($6.39/FIXTURE)(3 YEARS)/[(12,000 HR LIFE/6552 HOURS/YR)] = $73,498
LABOR COST OF 400W LAMP = (1765 FIXTURES)($6.39/FIXTURE)(3 YEARS)/[(20,000 HR LIFE/6552 HOURS/YR)] = $11,084

AW(21%) = (73,498 - 11,084)(A/F 21,3) = **$16,989**

# ALTERNATIVE 4: USING VENTURE METAL HALIDE FIXTURES IN PLANT

**DETERMINATION OF REPLACEMENT SAVINGS (SUBCONTRACTOR LABOR):**

BALLAST COST REPLACEMENT SAVINGS ARE NEGLIGLE; THEREFORE, THEY ARE NOT INCLUDED.

HOWEVER, LAMP REPLACEMENT SAVINGS AND REPLACEMENT LABOR SAVINGS ARE WORTH INCLUDING.

LAMPS SHOULD BE REPLACED AT END OF LIFE SINCE BOTH OF THEM DO NOT HAVE LIVES OF 3 YEARS
BALLASTS SHOULD BE REPLACED EVERY 15 YEARS (BALLAST LIFE = 15 YEARS).
USE A 3 YEAR PLANNING HORIZON FOR AW ANALYSIS (CONSISTENT WITH REPLACEMENT PROGRAM)

LABOR RATES:
1. SUBCONTRACTOR COST TO REPLACE THE LAMP AND CLEAN THE FIXTURE = $3.75 / FIXTURE (9 MINUTES / FIXTURE)
2. THE UNION COST TO REPLACE THE LAMP AND CLEAN THE FIXTURE = $6.39 / FIXTURE (9 MINUTES / FIXTURE)

**LAMP COST REPLACEMENT SAVINGS:**
LAMP LIFES: F96T12/LW/SS -> 12,000 HOURS, VENTURE 400W -> 20,000 HOURS

COST TO REPLACE F96T12 LAMPS = (7022 FIXTURES)(2 LAMPS/FIXTURE)($2.38/LAMP) = $33,425
REPLACE. COST = (3 YEARS)/[(12,000 HOURS LIFE/6552 HOURS/YR)] x (33,425) = $54,750

COST TO REPLACE 400W LAMPS = (1,590 M.H. LAMPS)($26.35/LAMP) = $41,897
REPLACE. COST = (3 YEARS)/[(20,000 HOURS LIFE/6552 HOURS/YR)] x (41,987) = $41,176

AW(21%) = (54,750 - 41,176)(A/F 21,3) = **$3,695** (A/F 21,3) = 0.2722

**SUBCONTRACTOR LABOR SAVINGS:**

LABOR COST OF F96T12 = (7022 FIXTURES)($3.75/FIXTURE)(3 YEARS)/[(12,000 HR LIFE/6552 HOURS/YR)] = $43,133
LABOR COST OF 400W LAMP = (1590 FIXTURES)($3.75/FIXTURE)(3 YEARS)/[(20,000 HR LIFE/6552 HOURS/YR)] = $5,860

AW(21%) = (43,133 - 5,860)(A/F 21,3) = **$10,146**

**UNION LABOR SAVINGS:**

LABOR COST OF F96T12 = (7022 FIXTURES)($6.39/FIXTURE)(3 YEARS)/[(12,000 HR LIFE/6552 HOURS/YR)] = $73,498
LABOR COST OF 400W LAMP = (1590 FIXTURES)($6.39/FIXTURE)(3 YEARS)/[(20,000 HR LIFE/6552 HOURS/YR)] = $9,985

AW(21%) = (73,498 - 9,985)(A/F 21,3) = **$17,288**

# APPENDIX D

# ILLUMINATION LEVELS PROVIDED BY THE ALTERNATIVES

# ALTERNATIVE 1: USING REFLECTORS WITH 1 OCTRON LAMP

**OFFICE AREA ILLUMINATION LEVEL ANALYSIS FOR PROPOSED SYSTEM:**

FC = FOOTCANDLES

TYPICAL OFFICE FLOOR DIMENSIONS = 528' X 96'
CEILING HEIGTH = 9'
DESKTOP HEIGTH = 3'
SPACE TO LIGHT = 9' - 3' = 6'
FC (AVERAGE REQUIRED) = 80 FC
FC (MEASURED) = 75 FC

**USING FORMULAS PRESENTED IN APPENDIX A:**

$$RCR = \frac{(5)(6\ \text{FEET})(528 + 96\ \text{FEET})}{(528)(96)\ \text{SQUARE FEET}} = 0.37$$

USED RCR = 0.37 TO FIND MF (MAINTENANCE FACTOR) FOR CALCULATIONS:

**ORIGINAL SYSTEM:** CU = 0.63, MF = 0.85, LLD = 0.80

$$\text{FC (INITIAL)} = \frac{(2925\ \text{LUMENS/LAMP})(2\ \text{LAMPS/FIXTURE})(1677\ \text{FIXTURES/FLOOR})(0.63)(0.85)}{(528)(96)\ \text{SQUARE FEET}}$$

$$= 103.6\ \text{FC}$$

$$\text{FC (MAINTAINED)} = \frac{(2925\ \text{LUMENS/LAMP})(2\ \text{LAMPS/FIXTURE})(1677\ \text{FIXTURES/FLOOR})(0.63)(0.85)(0.80)}{(528)(96)\ \text{SQUARE FEET}}$$

$$= 82.9\ \text{FC}$$

**PROPOSED SYSTEM:** CU = 0.86, MF = 0.85, LLD = 0.80

$$\text{FC (INITIAL)} = \frac{(2900\ \text{LUMENS/LAMP})(2\ \text{LAMPS/FIXTURE})(1677\ \text{FIXTURES/FLOOR})(0.86)(0.85)}{(528)(96)\ \text{SQUARE FEET}}$$

$$= 70.1\ \text{FC}$$

$$\text{FC (MAINTAINED)} = \frac{(2900\ \text{LUMENS/LAMP})(2\ \text{LAMPS/FIXTURE})(1677\ \text{FIXTURES/FLOOR})(0.86)(0.85)(0.80)}{(528)(96)\ \text{SQUARE FEET}}$$

$$= 56.1\ \text{FC}$$

# ALTERNATIVE 3: USING PARABOLIC FIXTURES IN OFFICE BUILDING

**OFFICE AREA ILLUMINATION LEVEL ANALYSIS FOR PROPOSED SYSTEM:**

FC = FOOTCANDLES

TYPICAL OFFICE FLOOR DIMENSIONS = 528' X 96'
CEILING HEIGTH = 9'
DESKTOP HEIGTH = 3'
SPACE TO LIGHT = 9' - 3' = 6'
FC (AVERAGE REQUIRED) = 80 FC
FC (MEASURED) = 75 FC

**USING FORMULAS PRESENTED IN APPENDIX A:**

$$RCR = \frac{(5)(6\ \text{FEET})(528 + 96\ \text{FEET})}{(528)(96)\ \text{SQUARE FEET}} = 0.37$$

USED RCR = 0.37 TO FIND MF (MAINTENANCE FACTOR) FOR CALCULATIONS:

**ORIGINAL SYSTEM:** CU = 0.63, MF = 0.85, LLD = 0.80

$$FC\ (\text{INITIAL}) = \frac{(2925\ \text{LUMENS/LAMP})(2\ \text{LAMPS/FIXTURE})(1677\ \text{FIXTURES/FLOOR})(0.63)(0.85)}{(528)(96)\ \text{SQUARE FEET}}$$

$$= 103.6\ FC$$

$$FC\ (\text{MAINTAINED}) = \frac{(2925\ \text{LUMENS/LAMP})(2\ \text{LAMPS/FIXTURE})(1677\ \text{FIXTURES/FLOOR})(0.63)(0.85)(0.80)}{(528)(96)\ \text{SQUARE FEET}}$$

$$= 82.9\ FC$$

**PROPOSED SYSTEM:** BASED ON 820 FIXTURES, CU = 0.83, MF = 0.85, LLD = 0.80

$$FC\ (\text{INITIAL}) = \frac{(2925\ \text{LUMENS/LAMP})(3\ \text{LAMPS/FIXTURE})(820\ \text{FIXTURES/FLOOR})(0.83)(0.85)}{(528)(96)\ \text{SQUARE FEET}}$$

$$= 100.1\ FC$$

$$FC\ (\text{MAINTAINED}) = \frac{(2925\ \text{LUMENS/LAMP})(3\ \text{LAMPS/FIXTURE})(820\ \text{FIXTURES/FLOOR})(0.83)(0.85)(0.80)}{(528)(96)\ \text{SQUARE FEET}}$$

$$= 80.1\ FC$$

# ALTERNATIVE 4: USING METAL HALIDE FIXTURES IN PLANT

**PLANT AREA ILLUMINATION LEVEL ANALYSIS FOR PROPOSED SYSTEM USING VENTURE METAL HALIDE LAMPS:**

FC = FOOTCANDLES

PLANT FLOOR DIMENSIONS = 920' X 600'
CEILING HEIGTH = 17'
LIGHTING TO FLOOR = 0'
SPACE TO LIGHT = 17' - 0' = 17'
FC (AVERAGE REQUIRED) = 65 FC
FC (MEASURED) = 65 FC

**USING FORMULAS PRESENTED IN APPENDIX A:**

$$RCR = \frac{(5)(17\ \text{FEET})(920 + 600\ \text{FEET})}{(920)(600)\ \text{SQUARE FEET}} = 0.23$$

USED RCR = 0.23 TO FIND MF (MAINTENANCE FACTOR) FOR CALCULATIONS:

**ORIGINAL SYSTEM:** CU = 0.66, MF = 0.85, LLD = 0.80

$$FC\ (\text{INITIAL}) = \frac{(5850\ \text{LUMENS/LAMP})(2\ \text{LAMPS/FIXTURE})(7022\ \text{FIXTURES/FLOOR})(0.66)(0.85)}{(920)(600)\ \text{SQUARE FEET}}$$

$$= 83.5\ FC$$

$$FC\ (\text{MAINTAINED}) = \frac{(5850\ \text{LUMENS/LAMP})(2\ \text{LAMPS/FIXTURE})(7022\ \text{FIXTURES/FLOOR})(0.66)(0.85)(0.80)}{(920)(600)\ \text{SQUARE FEET}}$$

$$= 66.8\ FC$$

**PROPOSED SYSTEM:** BASED ON 1590 FIXTURES, CU = 0.85, MF = 0.83, LLD = 0.80

$$FC\ (\text{INITIAL}) = \frac{(40{,}000\ \text{LUMENS/LAMP})(1\ \text{LAMP/FIXTURE})(1590\ \text{FIXTURES})(0.85)(0.83)}{(920)(600)\ \text{SQUARE FEET}}$$

$$= 81.3\ FC$$

$$FC\ (\text{MAINTAINED}) = \frac{(40{,}000\ \text{LUMENS/LAMP})(1\ \text{LAMP/FIXTURE})(1590\ \text{FIXTURES})(0.85)(0.83)(0.80)}{(920)(600)\ \text{SQUARE FEET}}$$

$$= 65.0\ FC$$