

*Customer Advanced Technologies Program
Technology Evaluation Report*

*T5 Fluorescent
High-Bay Lighting Systems*



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Table of Contents

<i>Introduction</i>	1
<i>Technology Description</i>	1
<i>Basecase Description</i>	
□ Metal Halide Systems	2
□ T8 Systems	2
<i>System Performance Comparison</i>	
□ System Ratings	3
□ Observations	3
<i>Completed Projects</i>	
□ Table of Completed Projects	4
□ Showcase Projects.....	5
<i>Conclusion</i>	
□ Lessons Learned Metal Halide Systems	7
□ Market Barriers and Potential	7

On the cover: Del Campo High School Gymnasium. Photo provided courtesy of 1st Source Lighting. The school District's decision to use T5s was largely based upon the success of similar projects completed under the Customer Advanced Technologies program.

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Introduction

SMUD's Customer Advanced Technologies (C.A.T.) program works with customers to encourage the use of and evaluate new technologies. The program provides funding for customers in exchange for monitoring rights. Completed demonstration projects include lighting technologies, light emitting diodes (LEDs), residential building shell construction, geothermal heat pumps, indirect / direct evaporative cooling, non-chemical water treatment and a wide variety of other technologies.

Technology Description

T5 fluorescent lamps are the basis for a new generation of fluorescent lighting products. The previous generation of fluorescent lighting was the T8 lamp, which is now the most-commonly used type of fluorescent lamp for office lighting applications.

Fluorescent lamps are classified by the shape and diameter of the lamps. T5 refers to a tubular fluorescent lamp that is five-eighths of an inch in diameter. A T8 lamp is eight-eighths or one inch in diameter.

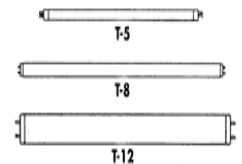
T5 lamps come in various shapes: linear, U-tube and compact fluorescent (a.k.a. biac) and are also available in high-output (HO) configurations. The scope of this evaluation is limited to T5HO systems used for high-bay applications.

The smaller diameter of these lamps provides good optical control and enables them to be used in applications traditionally (HID) systems such as metal halide. T5HO lamps are a very intense light source, which makes them a good choice for high-bay and indirect /direct lighting systems. However, care must be exercised when using these lamps in low ceiling applications to prevent visual comfort problems resulting from glare.

It is important to note that T5s usually require new fixtures and cannot be easily retrofitted into existing T8 or T12 systems. However, using fixtures specifically designed for T5 lamps optimizes performance and prevents the misapplication of other types of lamps – a common problem with T8 systems. Compared to metal-halide systems, T5s offer better lighting quality due to a higher color-rendering index, better light distribution, and lumen maintenance.

T5 Lamp Lengths

Nominal	Actual	
	T5	T8
24"	22.173"	23.725"
36"	33.984"	35.725"
48"	45.795"	47.725"
60"	57.606"	59.555"



T5 Fixture photos provided courtesy of 1st Source Lighting

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Base Case

Metal Halide

Conventional metal halide lamps have been the light source of choice for decades in high-bay applications. Almost all warehouses, industrial buildings, and warehouse retailers use metal halides. Other applications include multipurpose rooms and gymnasiums in schools and universities. Metal halide lamps are available in a variety of wattages and options. However, since 250 and 400-watt metal halide lamps are widely used for high-bay applications, they were chosen as the base case in this evaluation.

Advantages

- ❑ Good product selection (lamps and fixtures) from several manufacturers
- ❑ Fewer fixtures required (compared to standard fluorescent systems)
- ❑ Intense light source suitable for applications with high mounting heights
- ❑ Long lamp life (10,000 to 20,000 hours)
- ❑ Initial efficacy of ~75 to 83 lumens per Watt (lpw)

Disadvantages

- ❑ Poor lumen maintenance (~66% to 74% at 40% rated lamp life)
- ❑ Poor maintained efficacy (~54 to 55 lpw)
- ❑ Color shift
- ❑ Require up to 10 minutes to re-strike lamps after shutdown
- ❑ Ballast can be very noisy

T8 Systems

The T8 lamp has many favorable characteristics and has become the most commonly used lamp for office lighting applications. However, it is generally not suitable for high-bay applications. The main reason is that most T8 systems do not offer the optical control required to direct the light produced within the fixture down to the task, when used in applications with ceiling heights of over twenty feet.

Advantages

- ❑ Good product selection (lamps and fixtures) from several manufacturers
- ❑ Good lumen maintenance (~93% at 40% rated lamp life)
- ❑ Long lamp life (20,000 hours)
- ❑ Good color rendition (CRI > 80)
- ❑ No lamp re-strike period required
- ❑ Initial efficacy of ~93 lpw
- ❑ Maintained efficacy of ~86 lpw

Disadvantages

- ❑ More fixtures required (compared to metal halide systems)
- ❑ Not generally suitable for applications with high mounting heights over twenty feet

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System Performance Comparison

Performance Comparison	Standard T8 Lamps	T5HO (linear) (25°C / 35°C)	T5HO (biax)	250 Watt Metal Halide	400 Watt Metal Halide
Lamp Data					
Lamp Lumens (initial)	2,950	4,450 / 5,000	4,800	23,000	40,000
Rated Life (hours)	20,000	20,000	12,000	10,000	20,000
Color Rendering Index (CRI)	82	82	82	70	65
Mean Lumens	2,714	4,136 / 4,650	4,128	17,000	26,000
Lumen Maintenance (40% life)	92%	93%	86%	74%	65%
Re-strike time requirement	None	None	None	10 min	10 min
System Data					
Number of Lamps	4	4	4	1	1
Ballast Factor	90%	100%	100%	94%	94%
Initial System Lumens	10,620	17,800 / 20,000	19,200	21,620	37,600
Nominal System Watts	114	234	234	289	452
Initial System Efficacy (lpw)	93	76 / 85	82	75	83
Mean System Lumens	9,770	16,544 / 18,600	16,512	15,980	24,440
Maintained System Efficacy (lpw)	86	71 / 79	71	55	54

Initial System Lumens = (initial lamp lumens) x (# lamps) x (ballast factor)

Mean System Lumens = (initial lamp lumens) x (# lamps) x (ballast factor) x (lumen maintenance factor)

Observations

- ❑ It is important to note the dual ratings shown for the T5 linear lamp system (25°C and 35°C). One of the notable characteristics of the linear T5 lamp is that its performance improves at higher temperatures. At 35°C (95°F), a temperature often found within lighting fixtures, the T5HO lamp produces 5,000 initial lumens (85 lumens per watt) and 4,650 mean lumens (79 lumens per watt). ***This is forty-six percent more efficient than the 400-watt metal halide system.***
- ❑ There are two types of T5 high-output lamps represented in this analysis: the 48" linear lamps and the 24" biax lamp. Note that the rated life for the biax lamp is only 12,000 hours. Although this is better than a typical 250-watt metal halide lamp (10,000 hours), the linear T5HO is rated for 20,000 hours. ***Based upon these ratings, the maintenance costs for the linear T5HO system will be significantly lower than the biax system.***
- ❑ The metal halide systems have a steep lumen depreciation rate - a 26% to 35% reduction in lighting output at 40% of the rated lamp life. The lumen depreciation curve becomes even steeper as the lamp approaches the end of its life. ***Losses of 60% or more are quite common.***
- ❑ Overall, linear T5s are more efficient than T5 Biax and metal halides, but are less efficient than T8s. However, it is important to remember that T8s are generally not suitable for high-bay applications.

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Completed Projects

Several Customer Advanced Technology (C.A.T.) program projects were completed from 1999 through 2001. High-output T5 fixtures and lamps were used to replace a variety of metal halide and fluorescent systems. In all cases, the new T5 systems dramatically improved the quality of the lighting and substantially reduced energy costs. A summary of selected projects is presented below. For more details about these projects, please refer to the Appendix section of this report.

Summary of T5 High-Bay Projects

<i>Project Name</i>	<i>Basecase</i>	<i>New System</i>	<i>Demand Savings (%)</i>	<i>Energy Savings (%)</i>	<i>Project Cost</i>	<i>Annual Savings (\$)</i>	<i>Simple Payback (years)</i>
World Gym ²	400W Metal Halide	T5 HO Biax	49%	77%	\$6,643	\$3,735	1.8
Retail Pet Store	400W Metal Halide	T5 HO Linear	48%	48%	\$18,800	\$3,928	4.8
Recreation Hall	4 foot T8	T5 Compact	10%	10%	\$2,801	\$94	29.9
Manufacturing	4' & 8' T12	T5 HO Linear	19%	19%	\$4,625	\$256	18.1
Government (warehouse)	250W Metal Halide	T5 HO Linear	18%	18%	\$4,090	\$203	20.1
Government (exterior)	400W Metal Halide	T5 HO Linear	50%	50%	\$861	\$259	3.3
Galt H.S. New Gym ²	400W Metal Halide	T5 HO Linear	48%	48%	\$37,958	\$2,597	14.6
Galt H.S. Auditorium ²	400W Metal Halide	T5 HO Linear	48%	48%	\$7,117	\$266	26.7
Totals					\$82,896	\$11,338	7.3

² See 'Showcase Projects' on page five for more information

Note: the values presented in the table above were calculated based upon energy surveys that were completed by SMUD Energy Specialists. Actual monitored data was not available.

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Showcase Projects

Project: World Gym Racquet Ball Courts

Basecase:

- Eighteen 400-watt metal halide fixtures
- Demand = 8.1 kW
- Energy = 70,956 kWh per year
- Hours of operation: 8,760 hours per year
- Electrical costs: \$4,857 per year
- Light levels: Average of 36 foot-candles

New System:

- Retrofit fixtures with four T5HO Biax lamps
- Demand = 4.14 kW
- Energy = 16,146 kWh per year
- Hours of operation: 3,900 hours per year¹
- Electrical costs: \$1,121 per year
- Light levels: Average of 47 foot-candles
- Project Cost: \$6,643

Results:

- Demand reduction = 3.96 kW
- Expected annual energy savings = 54,810 kWh per year
- Electrical cost savings: \$3,735 per year
- Savings of nearly **50%** for all three categories
- Simple payback: 1.8 years

¹The T5 system enabled the World Gym to install lighting controls that significantly reduced the hours of operation.

Comments:

- The new T5 system provided 34% more light than the existing 400-watt metal halide system. This is primarily due to the high lumen depreciation rate of the metal halide system.
- The quality of the illumination improved dramatically due to the T5s truer color-rendering ability and better light distribution.
- Customer reaction: Very pleased. Commented on the improved quality of the lighting.
- Compared to conventional metal halides, T5s often provide energy savings of nearly 53% - assuming equal hours of operation. In some buildings, however, additional savings are achievable if the building owner is able to turn off the lights during normal working hours, when people are not present. Metal halides are normally left on continuously because of their re-



Photos of a racquetball court. Note how much brighter the court is after the T5HO system retrofit (shown on the left side).

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strike period. The World Gym was able to take advantage of this additional savings opportunity.

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Showcase Projects

Project: Galt High School: Gymnasium & Auditorium

Basecase:

- Fifty-seven, 400-watt metal halide fixtures
- Demand = 25.7 kW
- Energy = 85,536 kWh per year
- Hours of operation: Varied
- Electrical costs: \$5,965 per year
- Light levels: Average of 25 foot-candles

New System:

- Fifty-seven new high-bay fixtures with four, 4-foot, T5HO linear lamps
- Demand = 13.3 kW
- Energy = 44,479 kWh per year
- Hours of operation: Same as Basecase
- Electrical costs: \$3,102 per year
- Light levels: Average of 39 foot-candles
- Project cost: \$45,075



Results:

- Demand reduction = 12.3 kW
- Expected annual energy savings = 41,057 kWh per year
- Electrical cost savings: \$2,863 per year
- Savings of 48% for all three categories
- Simple payback: 15.7 years

Comments:

- The installation cost for this project was relatively high due to the fact that it was part of an overall modernization project (prevailing wages, architectural, engineering fees, etc.).
- Customer reaction:
 - Women's Basketball Coach "Lighting is much better...brighter!"
 - Athletic Director: "I'm very impressed; the lighting is even, no dull areas. This is the type of lighting that should have been originally installed."

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Conclusion

Lessons Learned

Based upon the results of numerous projects, T5HO lighting systems appear to be ideal for use in high bay applications traditionally limited to metal halide systems. T5 systems are energy efficient and offer higher color rendition, better lumen maintenance and even light distribution. Since T5HO systems do not require any time to re-strike the lamps, they can be combined with lighting control strategies (e.g. occupancy sensors) to further reduce energy consumption and costs.

Market Potential and Barriers

The potential market for T5HO systems is huge. This technology will work for virtually any application with ceiling heights of over fifteen feet. Examples include warehouses, industrial buildings, auto shops, retail establishments and gymnasiums.

The most significant barrier for T5 systems is the cost. As mentioned earlier, T5 systems usually require new fixtures. The economics are distinctly different for the two scenarios discussed below:

1. Retrofit. With no rebate, a payback period of about seven years is achievable for a pure retrofit situation. “Pure retrofit” means that replacement of the fixtures is not funded as part of a lighting upgrade – the demand and energy savings from the retrofit must cover the entire cost of the installation. Most building owners will not convert to T5s in a purely retrofit project. However, when T5s are combined with lighting control systems, the savings potential is much higher and the simple payback period may be much shorter.
2. Rehabilitation and new construction projects. New fixtures are required. The cost of the new metal halide lamps and fixtures can be subtracted from the cost of high-bay T5 lamps and fixtures when performing economic calculations. Payback periods for these types of projects are quite short.

The T5 systems are now readily available and have become a viable option for high-bay applications. Many lighting professionals expect T5HO systems to continue to grow in popularity and become more widely used. If this prediction holds true, the cost for new fixtures, lamps and ballasts should become lower as more manufacturers offer products.

Several manufacturers have recently introduced more efficient metal halide systems (e.g. pulse-start). Some experts believe that this is partly due to competition from the new T5HO systems. Ultimately this will lead to more choices and better lighting systems for customers.

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Technology Transfer

The successful demonstration projects completed under the Customer Advanced Technologies program were a major factor in successfully transitioning this technology to the mainstream market. SMUD's Commercial Energy Specialists now often recommend T5HO systems for high-bay applications. T5 systems have been eligible for Commercial and Industrial Efficiency Program incentives for the past two years and continue to grow in popularity.

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