Are All Footcandles Equal?

A Scotopic to Photopic (S/P) Ratio Primer
For the Energy Efficiency Professional

- With the emergence of highly efficient, affordable, T5 lamp/ballast systems, and fluorescent Hi-Bay fixtures designed to replace HPS and Metal Halide Hi-Bay fixtures, the question of whether all footcandles are equal is no longer simply an academic discussion.

- The lighting revolution that transformed office and retail facilities from T12 to T8 during the 1980's and 1990's, is now coming to the industrial facility world. The answer to the question of whether a footcandle produced by a Standard HPS400 or MH400 is equal to one produced by an 841k fluorescent can literally mean hundreds of thousands of dollars in yearly energy costs for large industrial facilities.

- For many years, lighting designers and occupants of industrial facilities have struggled to reconcile the difference between their perception of some illuminated environments, and the feedback that a traditional light meter provides. As a common example, an HPS system producing 40 footcandles may feel darker to the occupant of a space than a fluorescent system that produces 25 footcandles.

- The reason for this difference between perception and light meter is that a traditional light meter measures only photopic lumens, while the eye senses light based upon both photopic and scotopic lumens. In much the same way that the combined effect of temperature and humidity determine your comfort level, the combined effect of photoptic and scotopic lumens determine how well you see. Lighting engineers for many years have recognized the effect of scotopic sensitivity at night. More recent research demonstrates that scotopic illuminance has a strong effect at normal office light levels as well. By properly using S/P ratios, we can now quantify what we have long perceived, that we see better under "white" light sources than "yellow" light sources, and as a result, light sources with higher S/P ratios require less photopic lumens to meet visual performance objectives.

- There has been a great deal of research and engineering work on the subject of scotopic lighting, including the very recent development of a new type of light meter at Rensselaer Polytechnic Institute's Lighting Research Center. This new RFD meter measures standard illuminance as well as scotopic/photopic spectral responses and may be available commercially in the near future. Until new measuring devices are available or new IES standards are adopted which comprehend the effect of scotopic sensitivity, we would encourage lighting professionals to read the available studies, and reach your own conclusion as to whether you will include S/P ratios in your analysis of potential lighting solutions.

Recommended Reading

"Energy Efficiency Consequences of Scotopic Sensitivity" From the 1991 IESNA Annual Conference, by S.M. Berman, as published in the Journal of the Illuminating Engineering Society, Winter 1992.

"Essay by Invitation" From the February 2002 LD+A published by the IESNA, by Stan Walerczyk, LC

"The Re-engineering of Lighting Photometery" by Dr. Sam Berman, Edited by Brian Liebel, PE, can be found at http://www.lightresource.com/article9.html

"The Retinal Flux Density Meter" can be found at http://www.lrc.rpi.edu/posters/pdf/RetinalFluxDensity.pdf

S/P Adjusted Footcandle Chart

Light Source	Photopic FC	S/P Ratio	Task Application Factor	S/P Adjusted FC
T5HO/841	5	1.62	0.78	7
T5HO/841	6	1.62	0.78	9
T5HO/841	7	1.62	0.78	10
T5HO/841	8	1.62	0.78	12
T5HO/841	9	1.62	0.78	13
T5HO/841	10	1.62	0.78	15
T5HO/841	11	1.62	0.78	16
T5HO/841	12	1.62	0.78	17
T5HO/841	13	1.62	0.78	19
T5HO/841	14	1.62	0.78	20
T5HO/841	15	1.62	0.78	22
T5HO/841	16	1.62	0.78	23
T5HO/841	17	1.62	0.78	25
T5HO/841	18	1.62	0.78	26
T5HO/841	19	1.62	0.78	28
T5HO/841	20	1.62	0.78	29
T5HO/841	21	1.62	0.78	31
T5HO/841	22	1.62	0.78	32
T5HO/841	23	1.62	0.78	34
T5HO/841	24	1.62	0.78	35
T5HO/841	25	1.62	0.78	36
T5HO/841	26	1.62	0.78	38
T5HO/841	27	1.62	0.78	39
T5HO/841	28	1.62	0.78	41
T5HO/841	29	1.62	0.78	42
T5HO/841	30	1.62	0.78	44
T5HO/841	31	1.62	0.78	45
T5HO/841	32	1.62	0.78	47
T5HO/841	33	1.62	0.78	48
T5HO/841	34	1.62	0.78	50
T5HO/841	35	1.62	0.78	51
T5HO/841	36	1.62	0.78	52
T5HO/841	37	1.62	0.78	54
T5HO/841	38	1.62	0.78	55
T5HO/841	39	1.62	0.78	57
T5HO/841	40	1.62	0.78	58
T5HO/841	41	1.62	0.78	60
T5HO/841	42	1.62	0.78	61
T5HO/841	43	1.62	0.78	63
T5HO/841	44	1.62	0.78	64
T5HO/841	45	1.62	0.78	66
T5HO/841	46	1.62	0.78	67
T5HO/841	47	1.62	0.78	68
T5HO/841	48	1.62	0.78	70
T5HO/841	49	1.62	0.78	71
T5HO/841	50	1.62	0.78	73

Light Source	Photopic FC	S/P Ratio	Task Application Factor	S/P Adjusted FC
Metal Halide	5	1.49	0.78	7
Metal Halide	6	1.49	0.78	8
Metal Halide	7	1.49	0.78	10
Metal Halide	8	1.49	0.78	11
Metal Halide	9	1.49	0.78	12
Metal Halide	10	1.49	0.78	14
Metal Halide	11	1.49	0.78	15
Metal Halide	12	1.49	0.78	16
Metal Halide	13	1.49	0.78	18
Metal Halide	14	1.49	0.78	19
Metal Halide	15	1.49	0.78	20
Metal Halide	16	1.49	0.78	22
Metal Halide	17	1.49	0.78	23
Metal Halide	18	1.49	0.78	25
Metal Halide	19	1.49	0.78	26
Metal Halide	20	1.49	0.78	27
Metal Halide	21	1.49	0.78	29
Metal Halide	22	1.49	0.78	30
Metal Halide	23	1.49	0.78	31
Metal Halide	24	1.49	0.78	33
Metal Halide	25	1.49	0.78	34
Metal Halide	26	1.49	0.78	35
Metal Halide	27	1.49	0.78	37
Metal Halide	28	1.49	0.78	38
Metal Halide	29	1.49	0.78	40
Metal Halide	30	1.49	0.78	41
Metal Halide	31	1.49	0.78	42
Metal Halide	32	1.49	0.78	44
Metal Halide	33	1.49	0.78	45
Metal Halide	34	1.49	0.78	46
Metal Halide	35	1.49	0.78	48
Metal Halide	36	1.49	0.78	49
Metal Halide	37	1.49	0.78	50
Metal Halide	38	1.49	0.78	52
Metal Halide	39	1.49	0.78	53
Metal Halide	40	1.49	0.78	55
Metal Halide	41	1.49	0.78	56
Metal Halide	42	1.49	0.78	57
Metal Halide	43	1.49	0.78	59
Metal Halide	44	1.49	0.78	60
Metal Halide	45	1.49	0.78	61
Metal Halide	46	1.49	0.78	63
Metal Halide	47	1.49	0.78	64
Metal Halide	48	1.49	0.78	66
Metal Halide	49	1.49	0.78	67
Metal Halide	50	1.49	0.78	68

Light Source	Photopic FC	S/P Ratio	Task Application Factor	S/P Adjusted FC
Standard HPS	5	0.62	0.78	3
Standard HPS	6	0.62	0.78	4
Standard HPS	7	0.62	0.78	5
Standard HPS	8	0.62	0.78	6
Standard HPS	9	0.62	0.78	6
Standard HPS	10	0.62	0.78	7
Standard HPS	11	0.62	0.78	8
Standard HPS	12	0.62	0.78	8
Standard HPS	13	0.62	0.78	9
Standard HPS	14	0.62	0.78	10
Standard HPS	15	0.62	0.78	10
Standard HPS	16	0.62	0.78	11
Standard HPS	17	0.62	0.78	12
Standard HPS	18	0.62	0.78	12
Standard HPS	19	0.62	0.78	13
Standard HPS	20	0.62	0.78	14
Standard HPS	21	0.62	0.78	14
Standard HPS	22	0.62	0.78	15
Standard HPS	23	0.62	0.78	16
Standard HPS	24	0.62	0.78	17
Standard HPS	25	0.62	0.78	17
Standard HPS	26	0.62	0.78	18
Standard HPS	27	0.62	0.78	19
Standard HPS	28	0.62	0.78	19
Standard HPS	29	0.62	0.78	20
Standard HPS	30	0.62	0.78	21
Standard HPS	31	0.62	0.78	21
Standard HPS	32	0.62	0.78	22
Standard HPS	33	0.62	0.78	23
Standard HPS	34	0.62	0.78	23
Standard HPS	35	0.62	0.78	24
Standard HPS	36	0.62	0.78	25
Standard HPS	37	0.62	0.78	25
Standard HPS	38	0.62	0.78	26
Standard HPS	39	0.62	0.78	27
Standard HPS	40	0.62	0.78	28
Standard HPS	41	0.62	0.78	28
Standard HPS	42	0.62	0.78	29
Standard HPS	43	0.62	0.78	30
Standard HPS	44	0.62	0.78	30
Standard HPS	45	0.62	0.78	31
Standard HPS	46	0.62	0.78	32
Standard HPS	47	0.62	0.78	32
Standard HPS	48	0.62	0.78	33
Standard HPS	49	0.62	0.78	34
Standard HPS	50	0.62	0.78	34

S/P Adjusted FC = Photopic Fc x (S/P).78 [.78 exponent Task Application Factor] See PRD SP Ratio Primer for additional detail.

Precision
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Fluorescent Hi-Bay Comparison Based Upon Lamps at Rated Life Comprehensive of S/P Ratios

T5 Hi-Bay Systems

Hi-Bay System	Lamp Quantity & Type		Initial Lumens Per Lamp	Lumen Maint-enance	(A) EOL Lumens Per Lamp	(B) EOL Lumens All Lamps	Ballast Factor	Fixture Effic-iency	(C) EOL Lumens Per Fixture	S/P Ratio	(D) Net EOL Lumens Per Fixture	Fixture Input Watts	(E) Efficacy Net EOL Lumens/Watt
2L-T5HO	2	FP54-T5-HO	5,000	93%	4,650	9,300	1.00	0.92	8,556	1.62	12,465	117	107
3L-T5HO	3	FP54-T5-HO	5,000	93%	4,650	13,950	1.00	0.92	12,834	1.62	18,698	176	106
4L-T5HO	4	FP54-T5-HO	5,000	93%	4,650	18,600	1.00	0.92	17,112	1.62	24,930	234	107
5L-T5HO	5	FP54-T5-HO	5,000	93%	4,650	23,250	1.00	0.92	21,390	1.62	31,163	293	106
6L-T5HO	6	FP54-T5-HO	5,000	93%	4,650	27,900	1.00	0.92	25,668	1.62	37,395	351	107

T8 Hi-Bay Systems

Hi-Bay System	Lamp Quantity & Type		Initial Lumens Per Lamp	Lumen Maint-enance	(A) EOL Lumens Per Lamp	(B) EOL Lumens All Lamps	Ballast Factor	Fixture Effic-iency	(C) EOL Lumens Per Fixture	S/P Ratio	(D) Net EOL Lumens Per Fixture	Fixture Input Watts	(E) Efficacy Net EOL Lumens/Watt
4L-T8-HBF	4	F32-T8-841	3,100	92%	2,852	11,408	1.14	0.90	11,705	1.62	17,052	151	113
6L-T8-HBF	6	F32-T8-841	3,100	92%	2,852	17,112	1.14	0.90	17,557	1.62	25,578	228	112

HID Hi-Bay Systems

Hi-Bay System	Lamp Quantity & Type		Initial Lumens Per Lamp	Lumen Maint-enance	(A) EOL Lumens Per Lamp	(B) EOL Lumens All Lamps	Ballast Factor	Fixture Effic-iency	(C) EOL Lumens Per Fixture	S/P Ratio	(D) Net EOL Lumens Per Fixture	Fixture Input Watts	(E) Efficacy Net EOL Lumens/Watt
MH400	1	Std MH400	38,000	58%	22,040	22,040	1.00	0.75	16,530	1.49	22,561	458	49
HPS400	1	Std HPS 400	50,000	70%	35,000	35,000	1.00	0.75	26,250	0.62	18,080	464	39

Definitions:

EOL = End of Life. Comparison is based upon end of life (synonymous with rated life) lamp performance values.
S/P Ratio = Scotopic to Photopic Lumen Ratio
(A) EOL Lumens Per Lamp = Initial lumens x lumen maintenance.
(B) EOL Lumens All Lamps = EOL Lumens per lamp x lamp quantity.
(C) EOL Lumens Per Fixture = EOL lumens all lamps x ballast factor x fixture efficiency.
(D) Net EOL Lumens Per Fixture = EOL Lumens Per Fixture x (S/P).78 [.78 exponent Task Application Factor]
(E) Efficacy = Net EOL Lumens Per Fixture divided by fixture input watts.

Note:

- In addition to those used above, many factors affect fixture performance in the field. Mounting height, spacing, dirt depreciation, operating temperature, control systems, group relamping practices, age of existing system, and appropriateness of existing system should all be considered when specifying a retrofit solution.
- Further information, product cutsheets, answers to FAQ, IES files and photometric reports, available upon request.