Indoor Ice Rinks and LED Technology

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Hydro Québec

History of hockey in Canada

- Ice hockey appeared in Canada early in the 1800s.
- Lord Stanley of Preston, the Governor General of Canada, was such an avid hockey enthusiast that in 1892 he donated a trophy, known today as the Stanley Cup.

The *Montreal AAA* club captured the first Stanley Cup championship in 1892 (http://www.legendsofhockey.net)

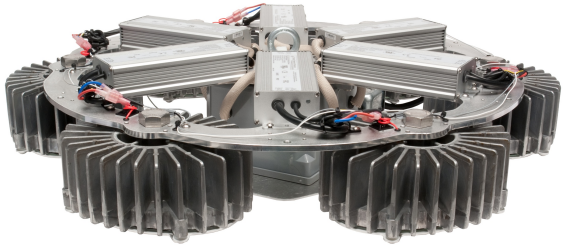
A Ladies Hockey Team, Toronto, Canada, ca. 1910 (http://www.civilization.ca)

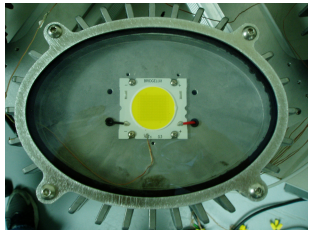
« *Technology* » tournament

> **Team no 1 (Metal Halide or MH):**

> **Team no 2 (T5HO):**

> **Team no 3 (LED):**





Referee of the tournament ???

HYDRO-QUÉBEC' S RESEARCH INSTITUTE (IREQ)

Hydro-Québec is focused on:

i) Meet its customers' needs and expectations

ii) « *Field demonstrations of new technologies are the most direct way to increase application understanding and build customer confidence, leading ultimately to market transformation* » (Electric Power Research Institute EPRI)

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SPECTRALUX LIGHTING AND TESTING LABORATORY
ISO/IEC 17025
NVLAP
NVLAP LAB CODE: 200899-0
EPA-recognized laboratory for ENERGY STAR

Partner with Hydro Québec

Private company (http://www.spectralux.ca)

Follow the « *technology* » game (Three periods)

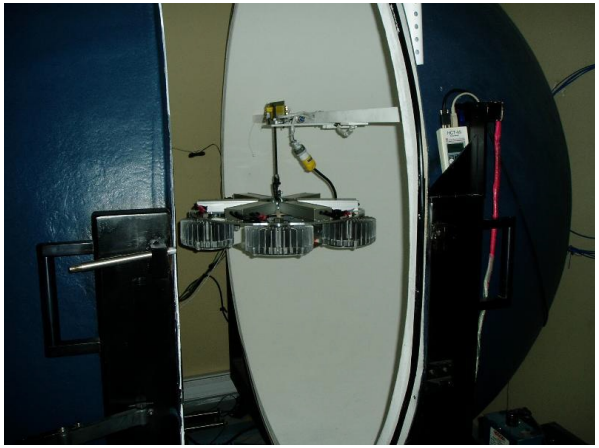
> Period no 1 : Integrating sphere

> Period no 2 : Goniophotometer

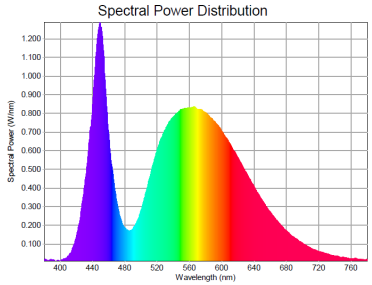
> Period no 3 : Field Application (light levels and environment)

http://canadiens.nhl.com (Old forum in 1937)

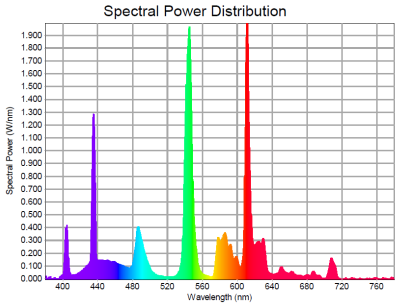
PERIOD no 1 : Integrating sphere



	Luminaire LED	Luminaire T5HO	Luminaire MH
Power (Watts)	373	326	460
Total lumens	33 075	26 847	31 279
Lumens /Watt	88,6	82,3	68
CRI	73	78	
CCT (°K)	5 208 ˚K	4 246 ˚K	n/a



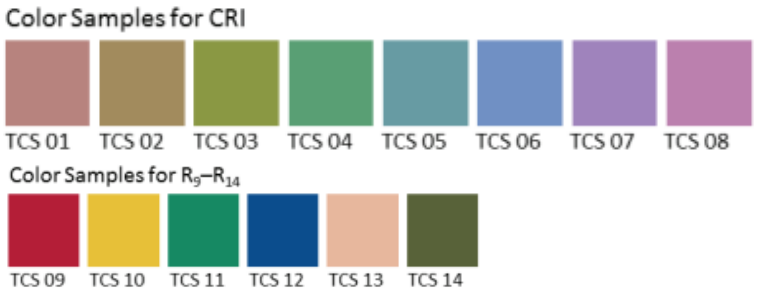
LED

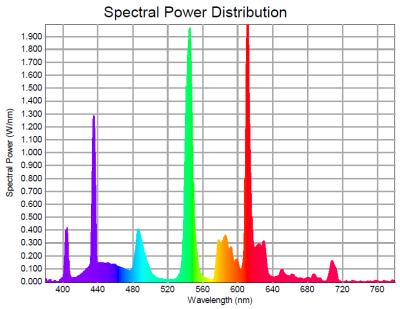


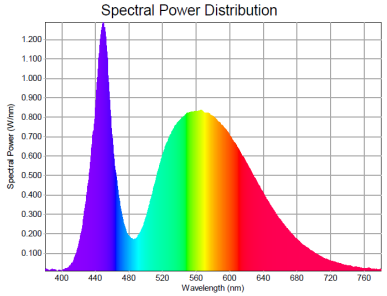
T5HO

PERIOD no 1 : Integrating sphere

Color quality scale or CQS
(GREAT « *Technology scoring goal* » from NIST)





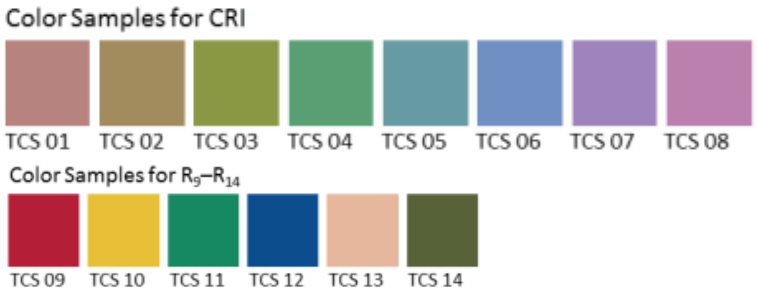


	T5HO	LED
R1	93	71,3
R2	87,4	77,5
R3	45,8	80,1
R4	83,9	73,6
R5	81,6	71,1
R6	70	67,8
R7	84,1	83,1
R8	76	62,2
R9	14,1	**-15,3**
R10	34,5	44,6
R11	67,4	68,8
R12	43,3	40,9
R13	93,6	71,9
R14	64,4	88,5

R9

PERIOD no 1 : Integrating sphere

Color quality scale or CQS
(Energy Star™ criteria for LED general service lamps)



R9 >0 for LED general service lamps meeting Energy Star™ criteria

R9 critical for some applications to see the red color (museum, hospital, meal cooking,…)

Probably not critical for an Indoor Hockey Ice Rink

PERIOD no 2 : Goniophotometer and dimming effect

- Increase in *lumens per Watt* with LED dimming
- *Maximum candela* at same angle with LED dimming

	100% of LED power	75% of LED power	50 % of LED power	25% of LED power
Test no	S1305212-R1	S1305222-R1	S1305221-R1	S1305213-R1
Power (Watts)	545,6	423	312,9	194,1
Candela maximum	16 888 Horizontal 15° Vertical 2,5°	13 894 Horizontal 15° Vertical 2,5°	10 758 Horizontal 15° Vertical 2,5°	6 799 Horizontal 15° Vertical 2,5°
Total lumens	48 519	39 922	30 966	19 585
Lumens /Watt	88,9	94,38	99,0	100,9

PERIOD no 2 : Goniophotometer and dimming effect

- No effect on % *zonal lumens distribution* with LED dimming

Table of lumens and % with LED dimming luminaire

Zone angle vertical	100% of LED power	75% of LED power	50 % of LED power	25% of LED power
0°-10°	1 580 (3,3%)	1 299,8 (3,3%)	1 008,2 (3,3%)	637,7 (3,3%)
10° – 20°	4 572,3 (9,4%)	3 761,3 (9,4%)	2 917,7 (9,4%)	1 845,6 (9,4%)
20° – 30°	7 051,0 (14,5%)	5 800,6 (14,5%)	4 500,2 (14,5%)	2 846,6 (14,5%)
30° - 40°	8 685,8 (17,9%)	7 145,8 (17,9%)	5 545,5 (17,9%)	3 508,5 (17,9%)
40° – 50°	9 214,5 (19,0%)	7 586,4 (19,0%)	5888,0 (19,0%)	3 723,7 (19,0%)
50° - 60°	8 431,4 (17,4%)	6 943,5 (17,4%)	5 383,7 (17,4%)	3 406,0 (17,4%)
60° - 70°	6 240,5 (12,9%)	5 128,7 (12,8%)	3 975,3 (12,8%)	2 513,9 (12,8%)
70° - 80°	2 560,3 (5,3%)	2 105,5 (5,3%)	1631,2 (5,3%)	1 028,4 (5,3%)
80° - 90°	182,9 (0,4%)	150,4 (0,4%)	116,6 (0,4%)	74,7 (0,4%)
90° - 180°	0 (0 %)	0 (0%)	0%	0 (0%)

PERIOD no 3 : Field Application (Light levels and environment)

Tasks and light levels required ???

Task no 1:
See and stop the puck

Task no 2:
Score goals

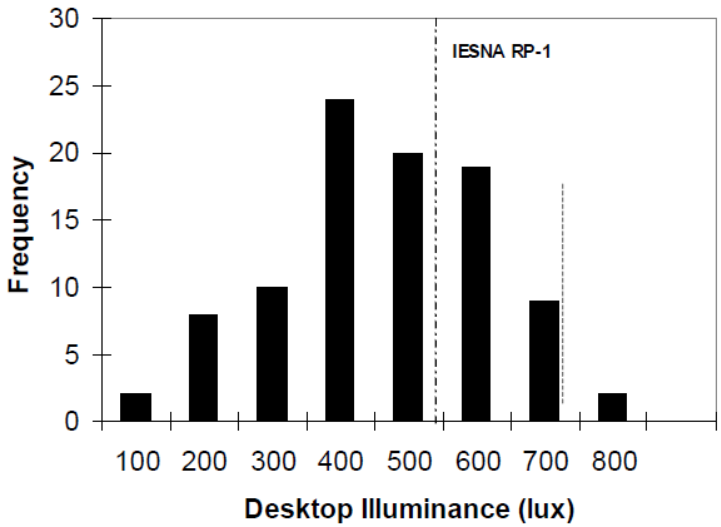
Task no 3:
Watch the game and SEE the game

PERIOD no 3 : Field Application (Light levels and environment)

(GREAT « *Technology scoring goal* » from NRC)

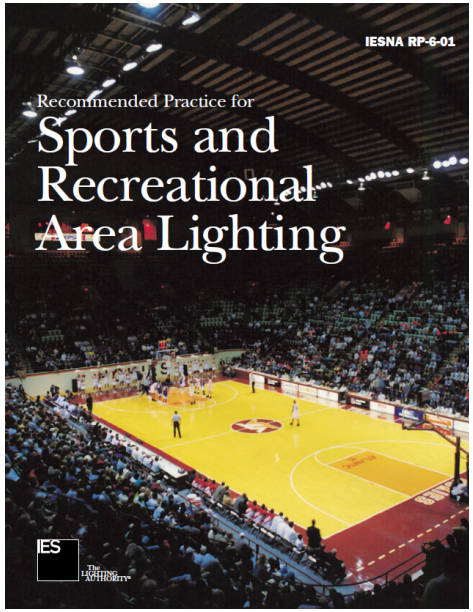
Veitch, J. A., & Newsham, G. R. (2000). Preferred luminous conditions in open-plan offices: Research and practice recommendations. *Lighting Research and Technology, 32,* 199-212.

> «*3.1.1 Desktop illuminance*. Luminous conditions in this investigation demonstrate wide individual variability. Desktop illuminance, for instance, varied from 83-725 lx.»



Preferred luminous conditions is not an easy game

PERIOD no 3 : Field Application (Hockey light levels)



FACILITY	CLASS			
	I	II	III	IV
Professional	X			
College	X	X		
Semi-Professional	X	X		
Sport clubs	X	X	X	
Amateur leagues		X	X	X
High Schools		X	X	X
Training Facilities			X	X
Elementary Schools				X
Recreational Events				X
Social Events				X

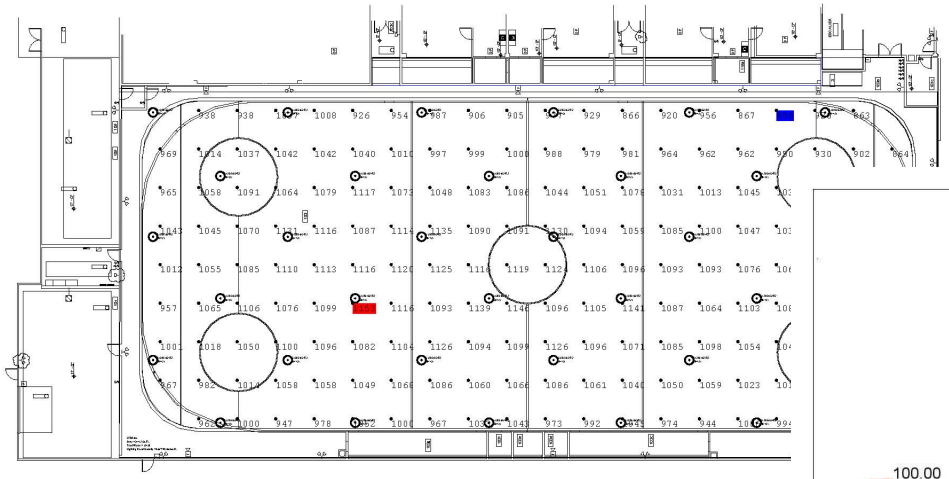
Class I – Facilities with spectator capacity over 5,000
Class II – Facilities with spectator capacity under 5,000
Class III – Facilities with some provision for spectators
Class IV – Facilities with no provision for spectators

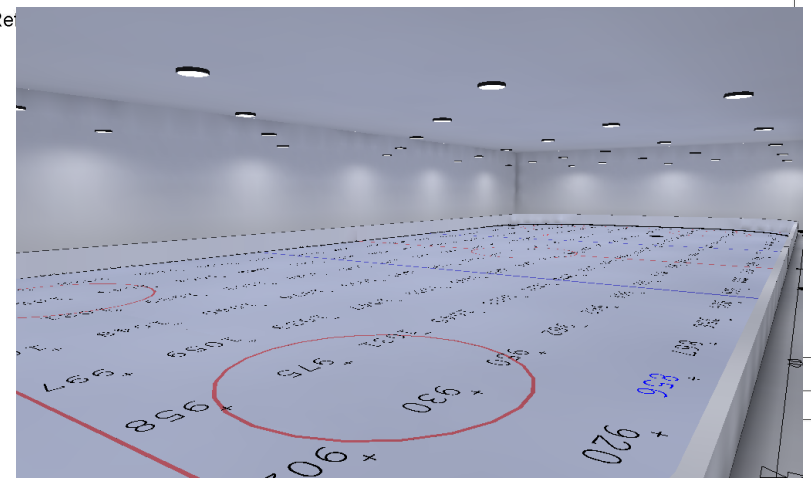
$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - x_{mean})^2}{n}}$$

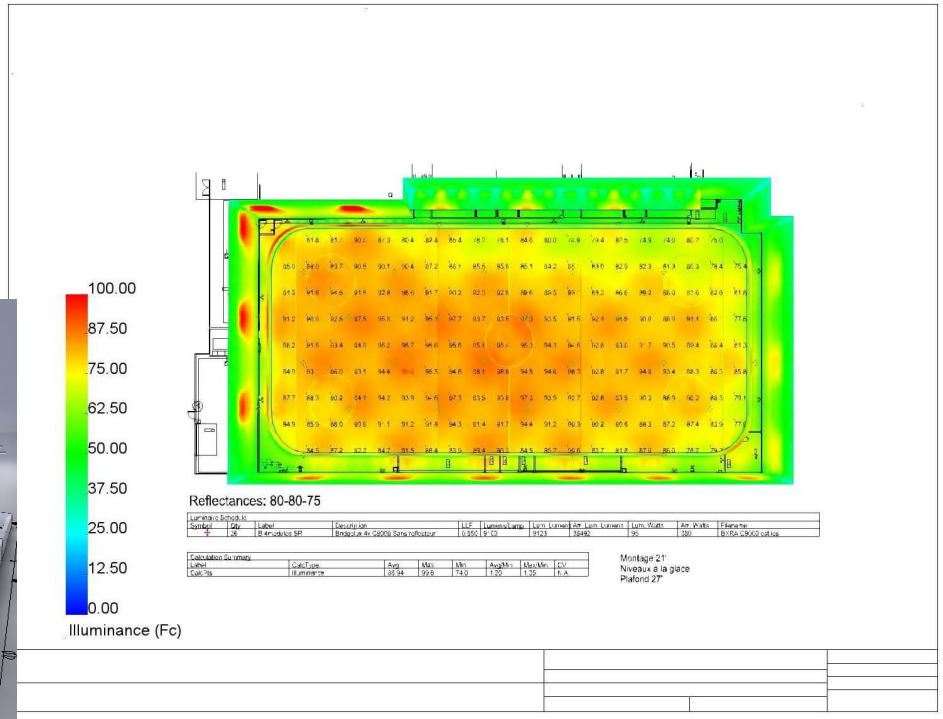
$$CV = \frac{\sigma}{x_{mean}}$$

FACILITY	CLASS			
	I	II	III	IV
Average illuminance (lux)	1250	1000	750	500
E_{max} / E_{min}	1.7 :1 or less	2.5 :1 or less	3 :1 or less	4 :1 or less
CV	0.13	0.21	0.25	0.30

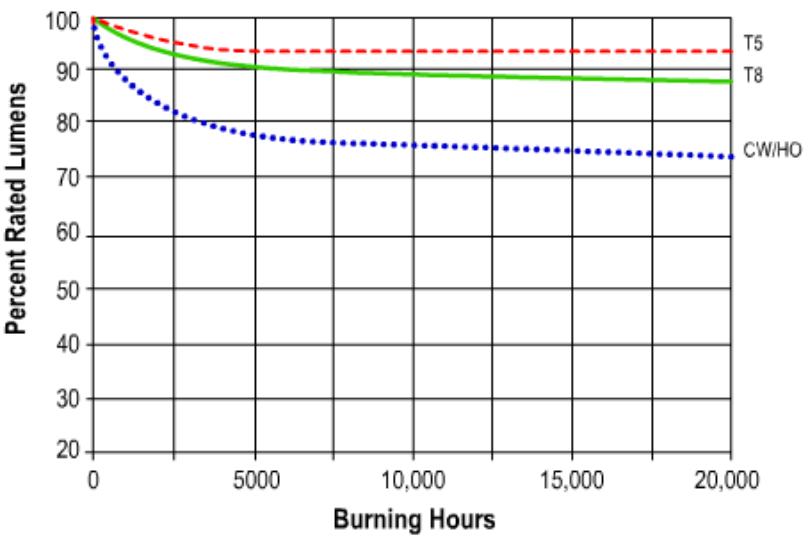
PERIOD no 3 : Field Application (Lighting simulation)





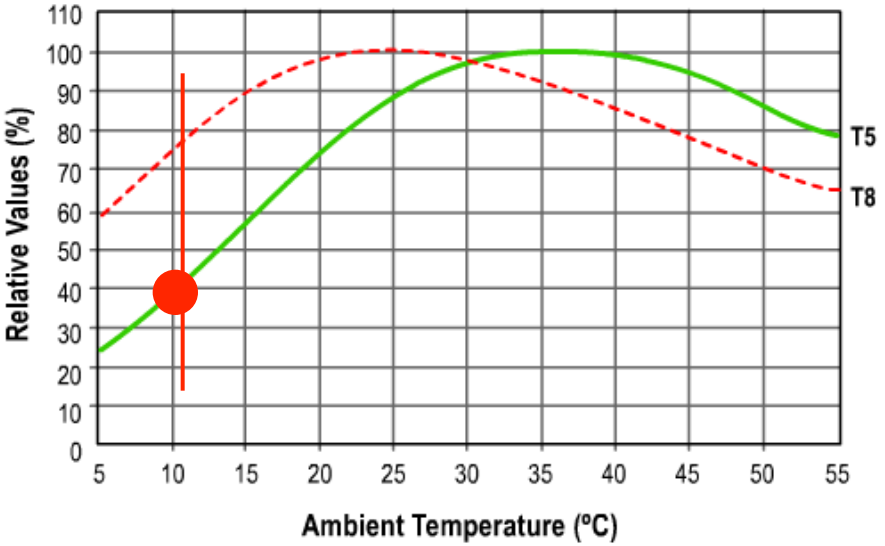


PERIOD no 3 : Field Application (Temperature effect on T5HO)



This diagram is based on OSRAM SYLVANIA's catalog, "Product Information Bulletin-PENTRON & PENTRON HO LINEAR T5."

11°C



This diagram is quoted from SILHOUETTE T5, T5 HO & T5 Circular Fluorescent Lamp Technology Guide, Philips Lighting Company.

Temperature : 11°C in an Interior Ice Rink

PERIOD no 3 : Field Application (Temperature effect on T5HO)

T5HO NOT SEALED luminaire vs. SEALED luminaire at 11°C

Luminaire condition	Not sealed (no lens)		Sealed (with lens)	
Test no	H1309241		H1309201	
Power (Watts)	319,4		355,2	
Total lumens	15 341		21 494	
lumens / Watt	48,0		60,5	
T ambiant (°C)	10,8		11	
Temperature	Tube	Air	Tube	Air
T1 (°C)	34,1	13,3	54,4	36,6
T2 (°C)	23,4	12	41,6	35,6
T3 (°C)	34,5	12,4	58,9	23,5
T4 (°C)	32,9	13,5	54,2	34
T5 (°C)	35,0	12,6	54,5	32
Mean (T1-T5) (°C)	32,3	12,8	52,7	32,3

Environmental chamber

Air in the luminaire not sealed : 12,8°C
Air in the luminaire sealed: 32,3 °C

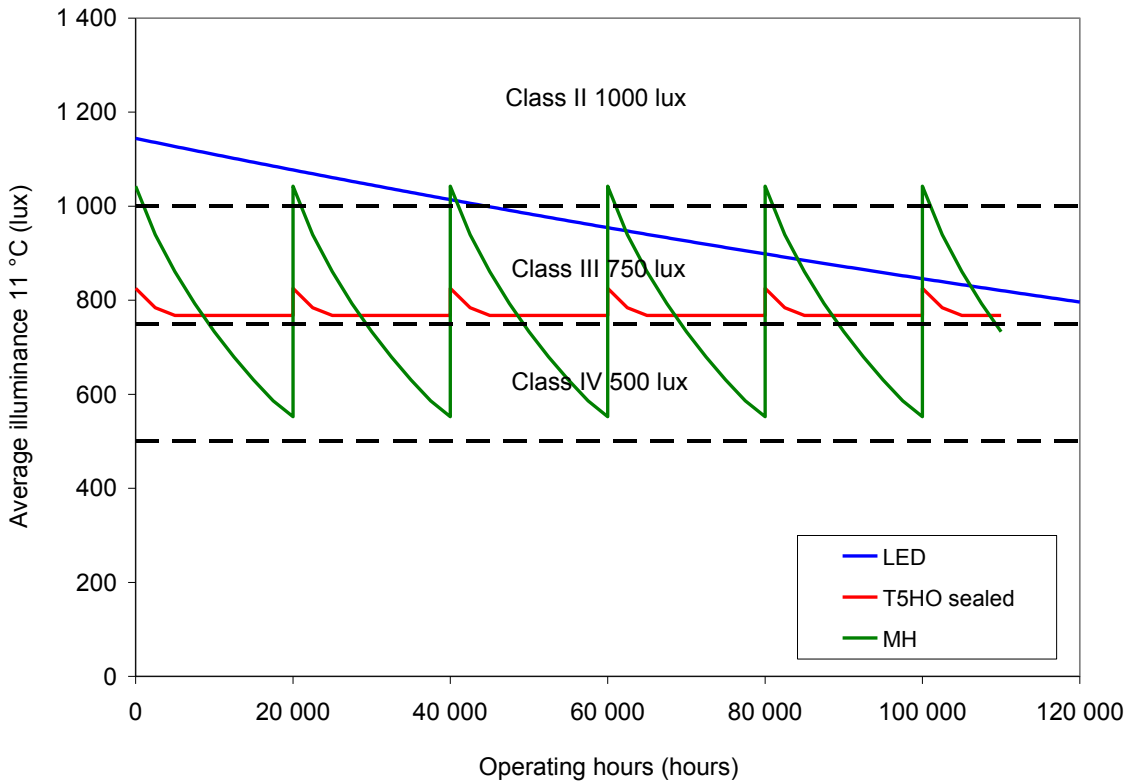
PERIOD no 3 : Field Application (Lux/Watt efficiency)

Technology	Average Initial illuminance (LLF = 1,0) at 25°C (lux)	Correction factor for 11°C operating temperature	Average Initial Illuminance (LLF = 1,0) at 11°C (lux)	Watt	Lux/Watt [1] at 11°C	Lux/Watt [1] at 25 °C
	(A)	(B)	= A x B			
LED	1 086	1,047	1 137	373	0,0847	0,0809
T5HO not sealed	699	0,47	328	329,5	0,0277	0,0589
T5HO not sealed	825	0,47	388	326	0,0330	0,070
MH	1 042	1,0	1 042	460	0,0629	0,0629

No 1

[1] Note: 36 luminaires used to calculate Lux/Watt
LED correction based on *In Situ Temperature Measurement Test* (ISTMT)

PERIOD no 3: Field application (Lumens depreciation)



10 years = 32 000 hours
20 years = 64 000 hours

$\Phi(t) = B \exp(-\alpha t)$
$B = 1{,}006$
$\alpha = 3{,}021 \times 10^{-6}$

31,9°C LED temperature below 55°C at 11°C

L_{70} = 120 000 hours

Reported L_{70} value: 36 000 hours (max. 6 times tested value TM-21)

PERIOD no 3: Field application (LED uniformity)

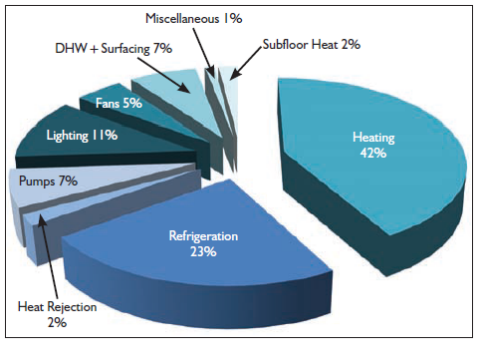
LED technology

> **CV : 0,07 meets Class 1**

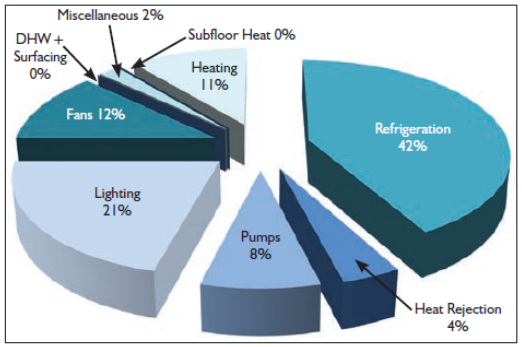
> **E_{max}/E_{min} = 1,35 meets Class 1**

FACILITY	CLASS			
	I	II	III	IV
Average illuminance (lux)	1250	1000	750	500
E_{max} / E_{min}	1.7 :1 or less	2.5 :1 or less	3 :1 or less	4 :1 or less
CV	0.13	0.21	0.25	0.30

Lighting Power Density of the Ice Rink



Inefficient arena (1,950,000 kWh).



Modified arena (8,40,000 kWh).

« The average amphitheatre is 24,000 ft² (2230 m²) (including stands for 500 people) with the ice sheet covering 16,327 ft² (1517 m²) (standardized 85 ft × 200 ft [26 m × 61 m] National Hockey League ice rink). »

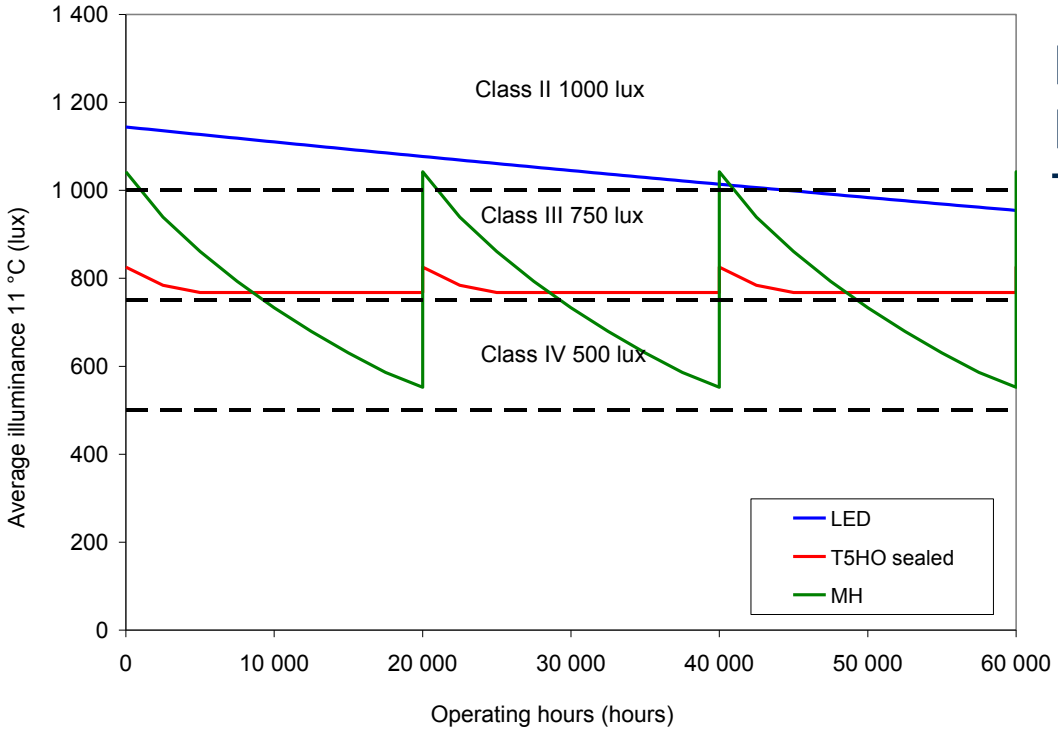
«The lighting of a non efficient amphitheatre uses approximately 32 kW for most ice activities. Most of the lighting fixtures are installed above the ice rink (1.9 W/ft² [20.5 W/m²]) and lower density lighting fixtures are installed above the stands (0.7 W/ft² [7.5 W/m²]) » Improving efficiency in ice hockey arenas, Laurier Nichols,P.E., Fellow ASRAE, ASHRAE Journal, June 2009

LED : 13 428 Watts / 1 517 m² = 8,85 W/m² **8,85 W/m²< 20,5 W/m²**

Energy cost for LED Ice Rink

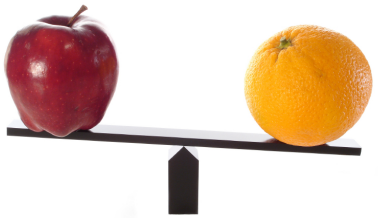
- LED : 373 Watts/luminaire
- Number of LED luminaire : 36
- Total Power for Ice rink : 13 428 Watts
- 100 hrs/week
- 32 weeks/year (8 months/year)
- 100 hrs/week x 32 weeks/year = 3 200 hrs/year
- 13 428 Watts x 3 200 hrs = 43 000 kWh/year
- 43 000 kWh x 0,09$/kWh = 3 870 $/year

Energy Cost / year ($)



MH : 4 770 $ (460 Watts)
LED : 3 870 $ (373 Watts)
T5HO : 3 380 $ (326 Watts)

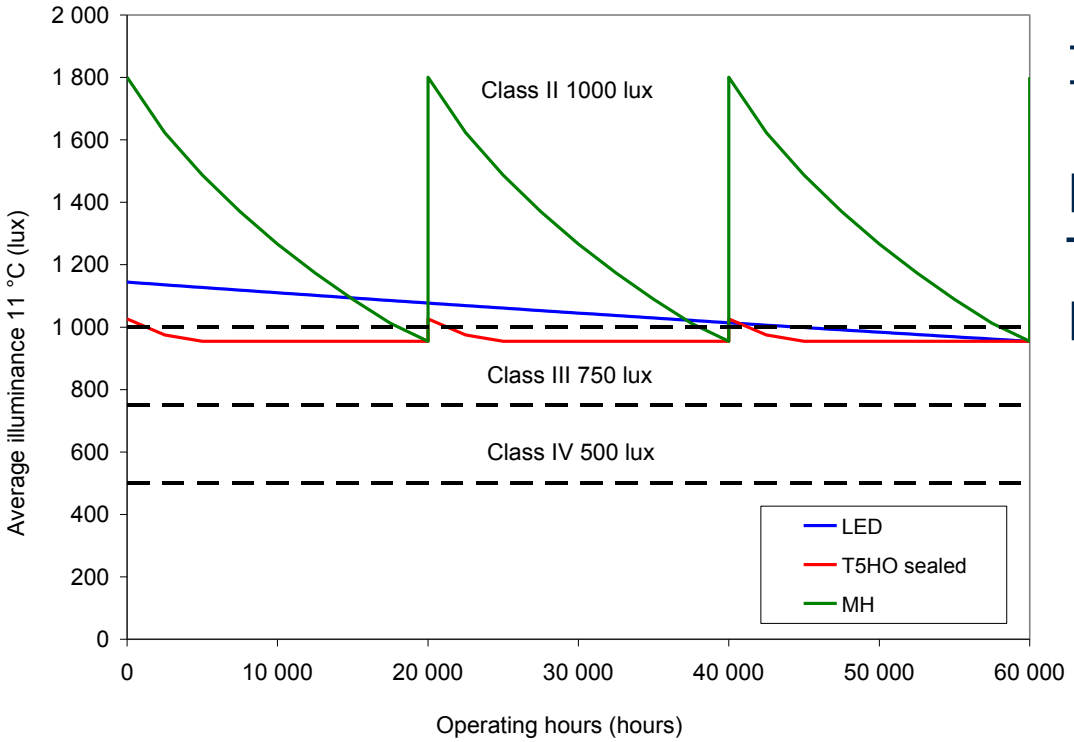
NOT FAIR SINCE
NOT THE SAME
LIGHT LEVELS



10 years = 32 000 hours
20 years = 64 000 hours

Note: 0,09 $/kWh

Energy Cost / year ($)
(Same light level at 60 000 hours)



10 years = 32 000 hours
20 years = 64 000 hours

Note: 0,09 $/kWh

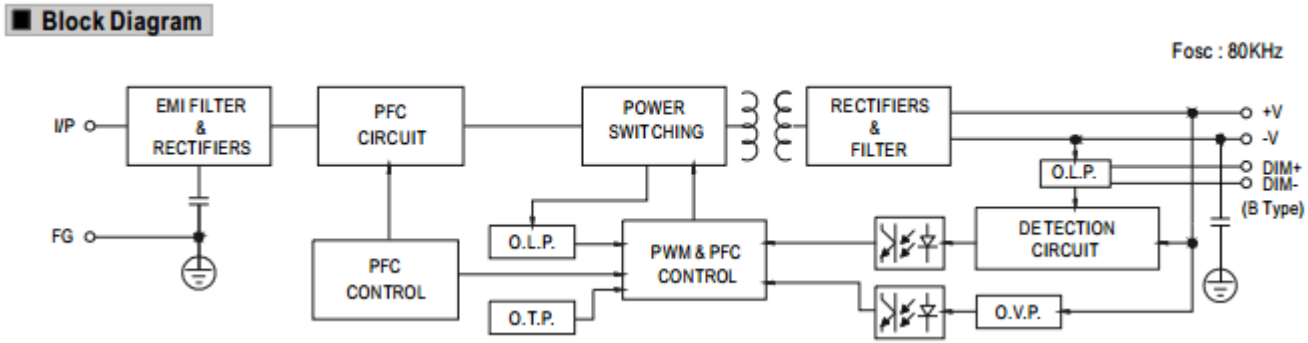
Installed Power

MH : 28 616 Watts
T5HO : 14 600 Watts
LED : 13 428 Watts

Energy cost / year ($)

MH : 8 241 $
T5HO : 4 205 $
LED : 3 870 $

LED dimming & driver



Dim 0-10Vdc

347 Vac Input Line Voltage

Power factor > 0,9

Total Harmonic Distorsion rate (THD)< 20%

Conclusion : Ice ready for LED technology

Lux / Watt = Focus on healthy and productive buildings instead of blindly wrecking the building in the name of energy conservation

LED Ice Rink (Victoriaville, Qc)

MERCI
THANKS

André Laperrière, ing. M.Sc.A.

Laboratoire des technologies de l'Énergie d'Hydro-Québec

Hydro Québec

IREQ Hockey Club, 1988