Seattle 2012
32nd National Narrow Gauge CONVENTION

Lighting Your Layout

NNGC Bellevue WA
September 2012

© Max Maginness MMR
September 2012 v 1.8d

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In Memory of
Jim Noonan
1924 - 2006

- for his was the brightest layout of them all.

What This Clinic Will Cover

- The Wit and Wisdom of Master John A.
- Lighting Basics 101 (+ a bit)
- Illumination levels for layouts – sample measurements
- Light sources.
- Lighting appearance to the eye and camera
- Layout lighting installation methods
- Calculating your requirements
- Basic good practices
- Recommendations

- Practical lighting basics – those with artistic stage lighting and photography ambitions can start from here.

The John Armstrong Lighting Rules

A LAYOUT LIGHTING SYSTEM should do more than just shed light on the layout so we can see the trains:

- **It should simulate sunlight.** Practically all published railroad photographs (especially color) are taken in sunshine. Night, fog, and storms may enhance the mood and quality of many scenes, but cloudy-day shots are usually not worth taking unless the occasion cannot be repeated. One of the attractive features of model railroading is the opportunity to control the environment, so we should go first class.
- **It should not generate unnatural effects.** Multiple shadows, shadows on the backdrop, undue variations in light intensity, and improper color balance are to be avoided. These problems are not entirely caused by the lighting system, but the system should be designed so that it adds no *new* complications to existing artlessness.
- **It should be unobtrusive.** No light should shine directly into the eye of the beholder, nor should it illuminate things that don't contribute to the effectiveness of the scene (such as contour face boards). Light fixtures and shades should not hit you on the head or otherwise get in the way, nor should they unduly impede work on the railroad.
- **It should be inexpensive to install and operate.** Consumable components (bulbs and tubes, mainly) should be readily available at low cost; light fixtures should be selected on the basis of reasonable initial cost. Consider both the energy consumption and the heat generated by the type and size lighting that you choose.
- **It should be easy to maintain.** Inaccessible fixtures are to be avoided. Murphy's Law says the bulbs in them will always burn out first while the bulbs that are easy to change burn on.
- **It should be safe.** Your lighting system should not increase the likelihood of burning down your house, electrocuting yourself, or of having heavy objects fall onto your models or right of way.
- **It should be good for other purposes, too.** Where possible, the system should be designed to provide storage space, convenient power sources for tools, and other side benefits, as long as the add-on features don't get in the way of the primary purpose.

Bright ~ sunlight

Natural shadows
Good color rendition

Not in your face

Many more options now than 1978

Access

No kludges

Part of the whole room set up

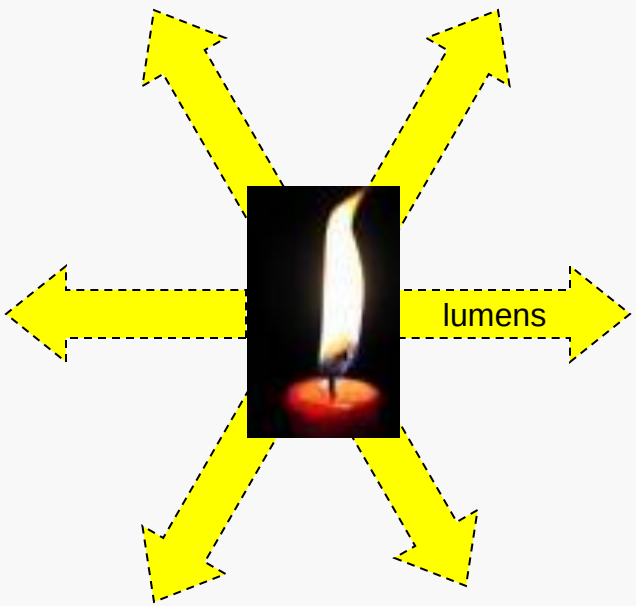
From: "John Armstrong on Creative Layout Design" Kalmbach, 1978

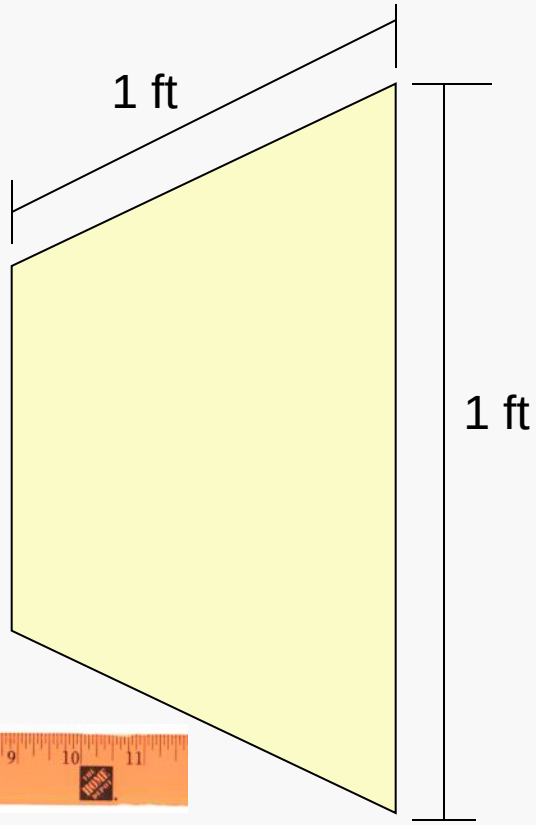
Lighting Basics

Basics - Footcandles and All That

"candlepower" - intensity in a given direction

1 cp ~ 12.5 lumens

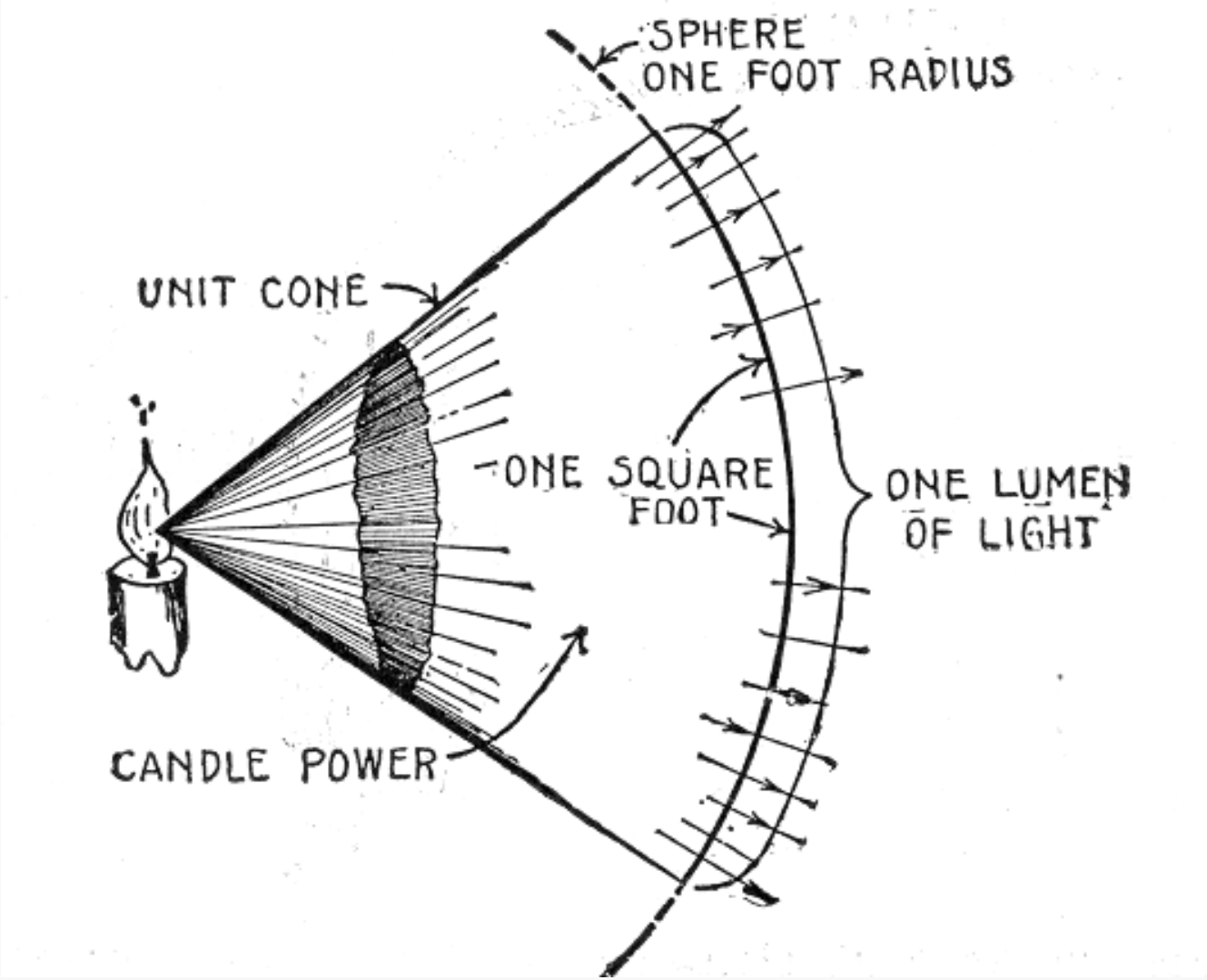




Light on area = 1 footcandle (fc) or 1 lumen per square foot.

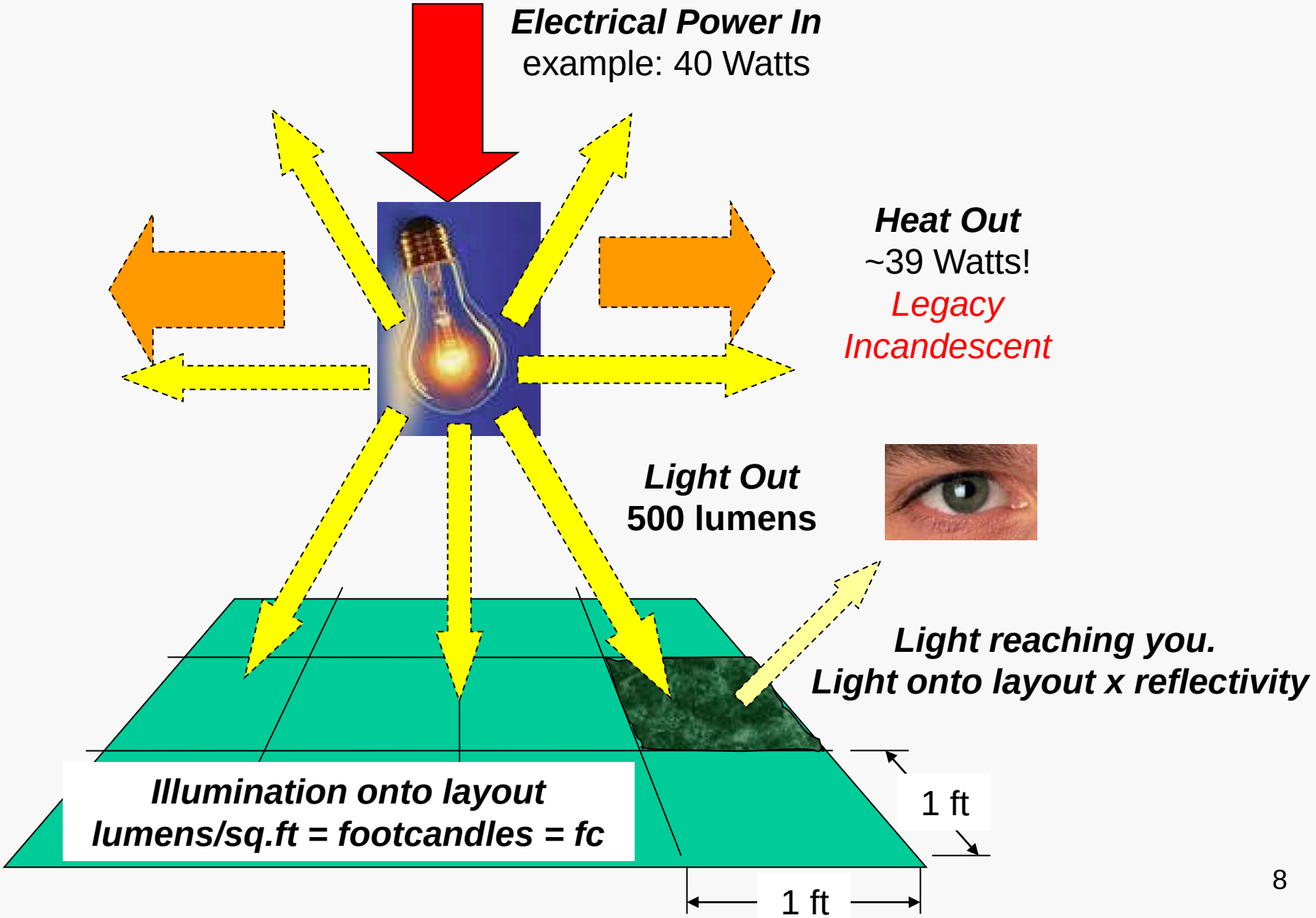
(international unit is "lux" = 1 lumen per square meter. 1 fc ~ 10 lux)

Nothing new here!



from: Hawkins Electrical Guide 1917.

Layout Lighting 1



Layout Lighting 2

From the Previous Drawing.

1. Illumination onto Layout – Estimate.

   - Lamp output = 500 lumens (*about 12 lumens/watt*)
   - 4 feet above layout *(illumination falls as square of distance)*
   - No reflectors behind lamp

   Illumination on layout surface ~ 2.5 lumens/sq ft. – very dim!
   Without reflectors most light is lost.

2. Reflection from layout – the light you or a camera sees

   - White paint more than 75%
   - Colorado midsummer scenery or desert ~ 25%
   - Dark Conifers - less than 10%

Scenery and structures need to be considered – what may seem bright enough on the "Plywood Pacific" starting point will look dimmer and dimmer as you add the scenery.

How do we arrive at a target value for Illumination?

- Its much better to install the lighting before the layout detail unless you like ladder acts.

- How to calculate what is needed?
  - Domestic and Industrial Standards and Recommendations
  - Measurements and “impression” on sample layouts with “good” lighting.
  - Experiments on your layout – viewing and photographs - but this is after the fact !!!!

Domestic and Industrial Standards and Recommendations

Recommended Domestic Light Levels:	
Dining*	10–20 fc
Kitchens	20–55 fc
Casual Reading	20-55 fc
Intensive Reading, Study	55-110 fc
Workshop	55–110 fc
Model building – high detail	110–210 fc
** May be adjusted in proportion to culinary skills!*	

Recommended Work Area Light Levels:	
Corridors	10–20 fc
Office: Large print	20–55 fc
Average Reading	50-100 fc
Difficult Reading	100-200 fc
Simple assembly	20-50 fc
Moderate assembly	50-100 fc
Complex assembly	100-200 fc
Fine assembly	200-500 fc
Operating Theater	1800 fc

These are under conditions of mostly reflective areas - scenery can be very light absorbent so more light is often needed

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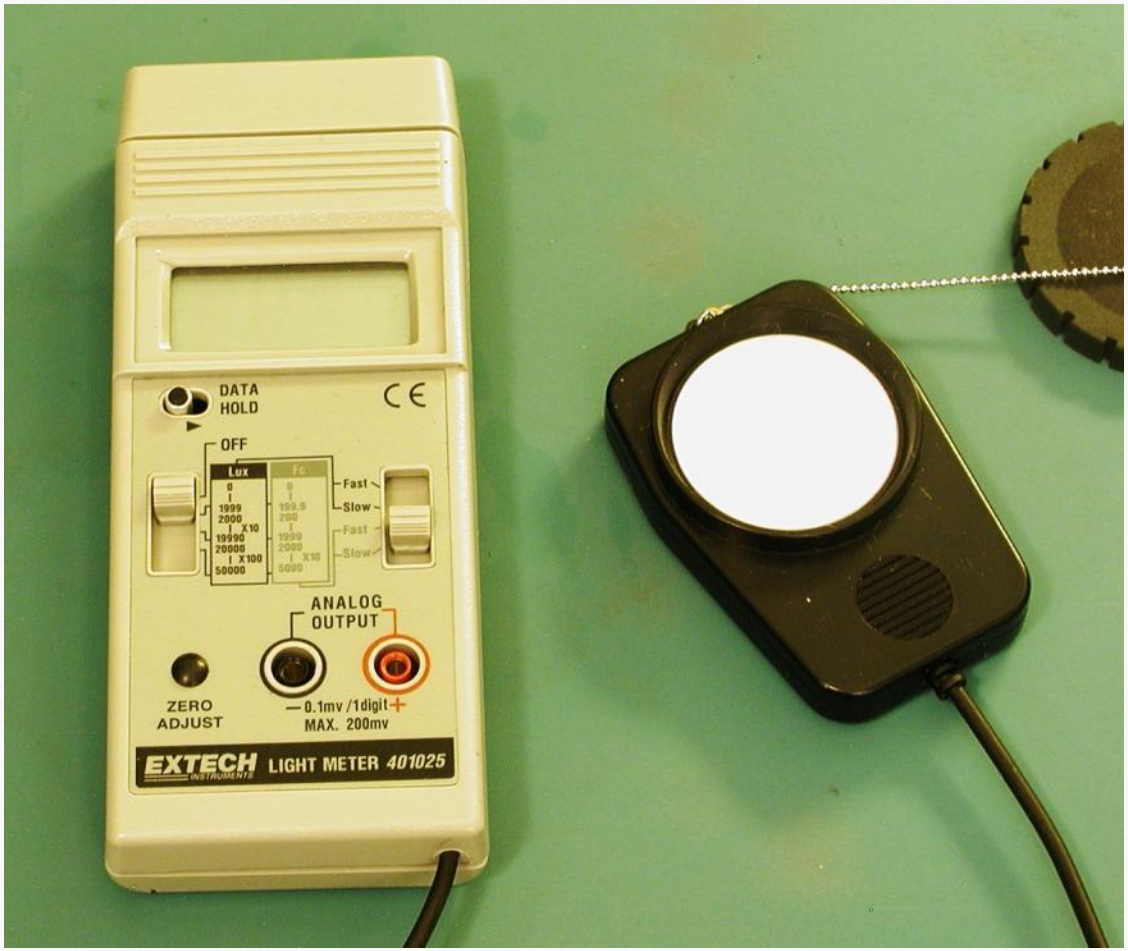
This suggests a range for layout lighting ~ 50-200 fc

Measuring the Light



Light Meter

Typical readings

- High noon August 16 2012, Redmond WA – 9,600 fc

  Overcast day - 100 fc

- Full moonlight – 1/100 fc

A 1 million to 1 change

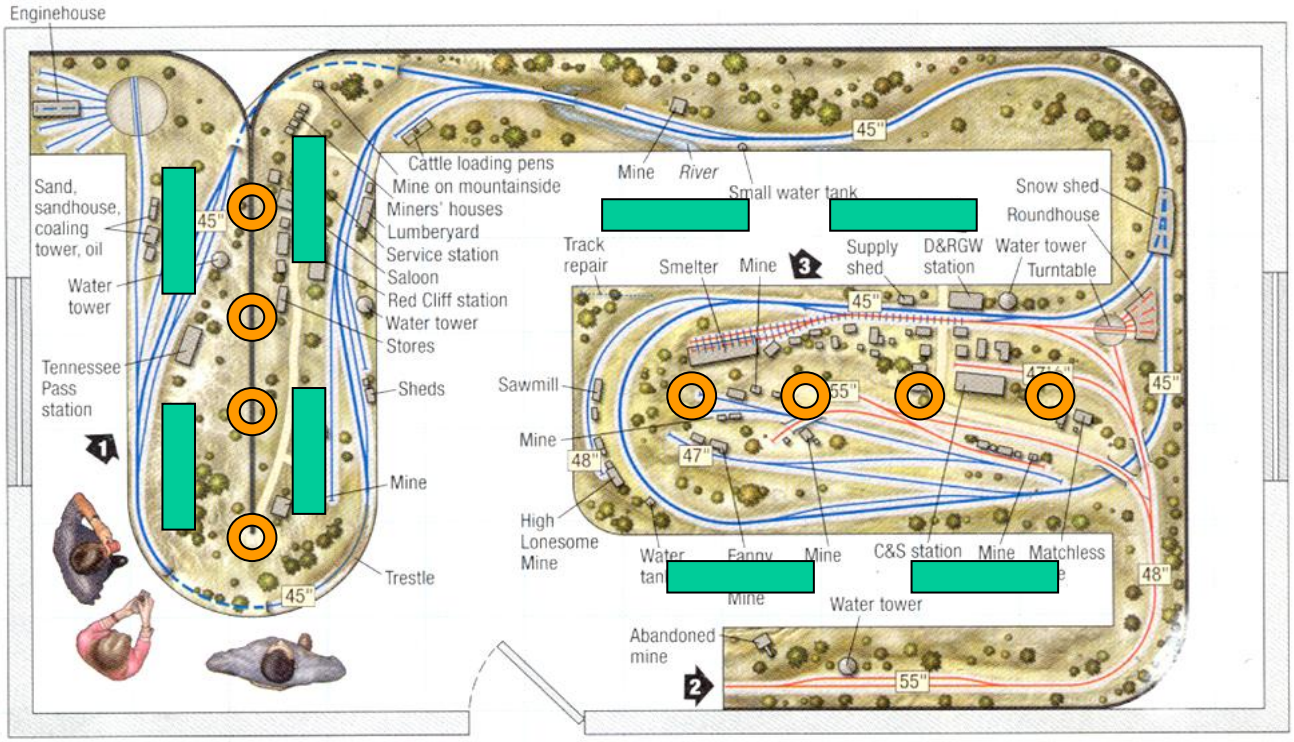
- *Human eye is very accommodating*
- *Camera automatic exposure has a more limited range.*

Layout Examples

LAYOUT LIGHTING

2 tube fluorescent

60 W incandescent



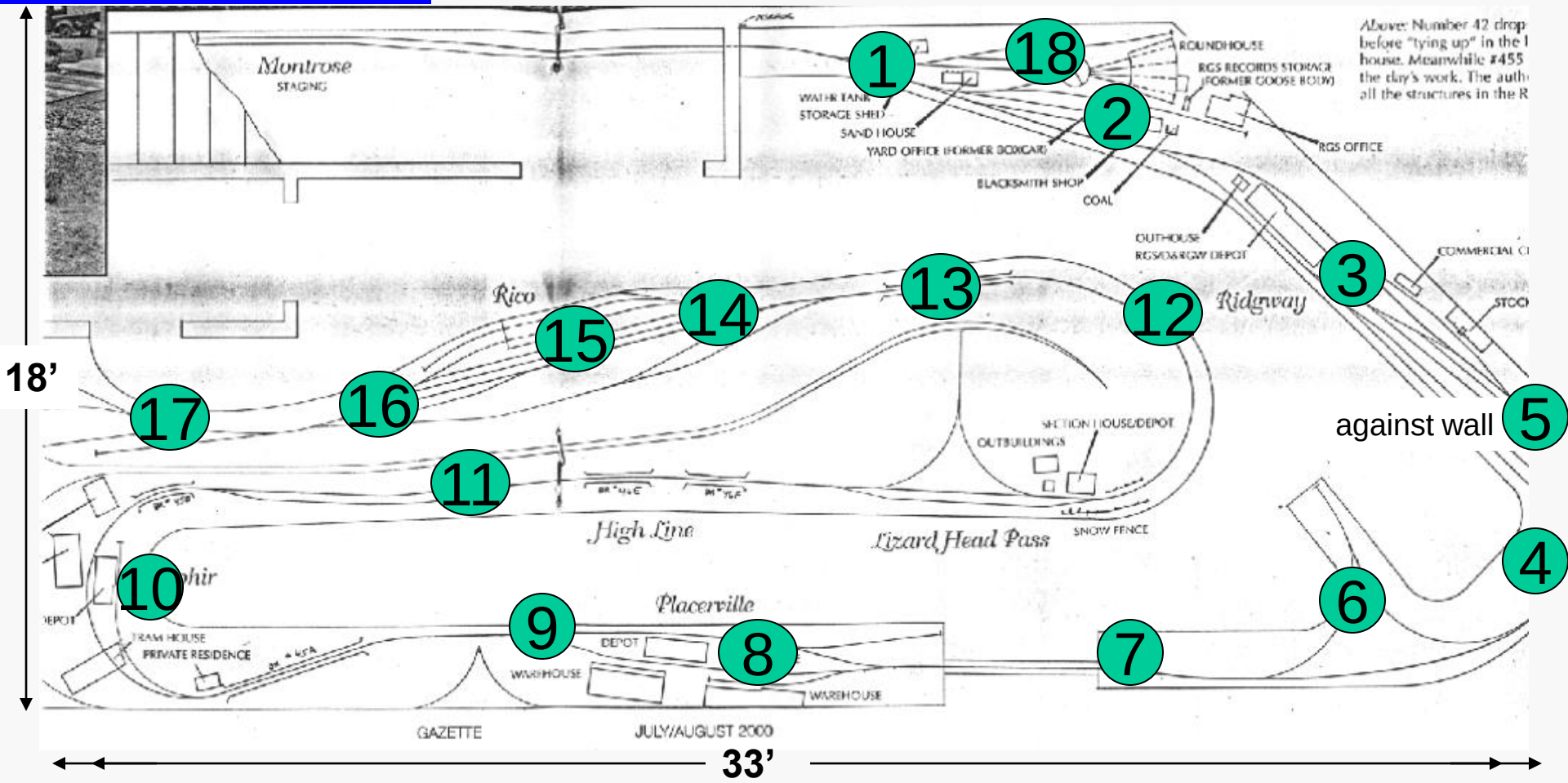
Tony Richter: MR Feb 2007:

- 16x 40 watt fluorescents
- 8x 60 watt incandescent
- Room area 329 sq ft
- Layout area 160 sq ft.
- No valances.

Fluorescent = 32,000 lumens (*50 lumens/watt*)
Incandescent = 7,000 lumens (*15 lumens/watt*)
Total: = 39,000 lumens
Area covered ~ 260 sq ft. (> layout surface)
At 50% effectiveness, average illumination =
39,000 x 0.5 / 260 = *75 fc.*
Power taken: 16x40 + 8x60 = 1120 watts
4.3 watts/sq ft of area illuminated.

LAYOUT LIGHTING

Layout F1/F2



Location	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Nov 2005	47	43	29	19	13	36	21	20	32	28	13	20	31	26	15	30	57	62

Light measurements in foot candles Average: *Nov 2005 = 31 fc. Jan 2007 = 72 fc.*
Jan 2007: 42, 34 watt T8 3400k tubes behind diffusers. Total lumens at tubes = 100,000
Total Electrical Power: 1430 watts, ~ 5watts/sq ft of layout surface (50% of room area)

LAYOUT LIGHTING

Layout and Lighting Scheme	Maximum Illumination	Minimum Illumination	Notes
A. Daylight fluorescent + halogen Spots	132 fc	81fc	Ceiling mounted. ~ 50”above layout
B. Daylight fluorescent	165 fc	29 fc (projecting)	Upper layer mounted. ~ 15” above layout
C. Philips F32T8 tubes “natural sunshine”	238 fc	66 fc (tube gap)	New tubes, no diffusers, at ~25”
D. Daylight fluorescent + incandescent lamps	129 fc	22 fc (dark corner)	Lights average height above layout 38”
E. “full spectrum” fluor. + 12 volt halogen spots	104 fc	58 fc	Lights ~ 54’ above layout. Black ceiling.
F1. “cool white” fluorescent.	62 fc	13 fc	Lights ~ 42” above. diffuser fittings
F2. 3400 K fluorescent	*143 fc*	*40 fc*	*21x 2 tubes F8= 1430W*
Overall Average	***139 fc***	***48 fc***	

Illumination Measurements on Representative (local) Layouts

- So we can arrive at a **"how bright"** requirement
  - levels in the range of 50 – 200 fc recommended.
  - not uniform across layout is OK, even desirable for artistic presentation.
- Now we need to consider the **type** of lighting used especially for **power needed** and the **color** impression.
  - *Color Temperature* – measure of color spectrum from light sources - red through blue (*degrees Kevin*)
  - *Color Rendering Index CRI* - how well colors are reproduced compared to daylight*. 0-100 range (100 = same as daylight.)

(**or an incandescent lamp for sources <5000°K)*

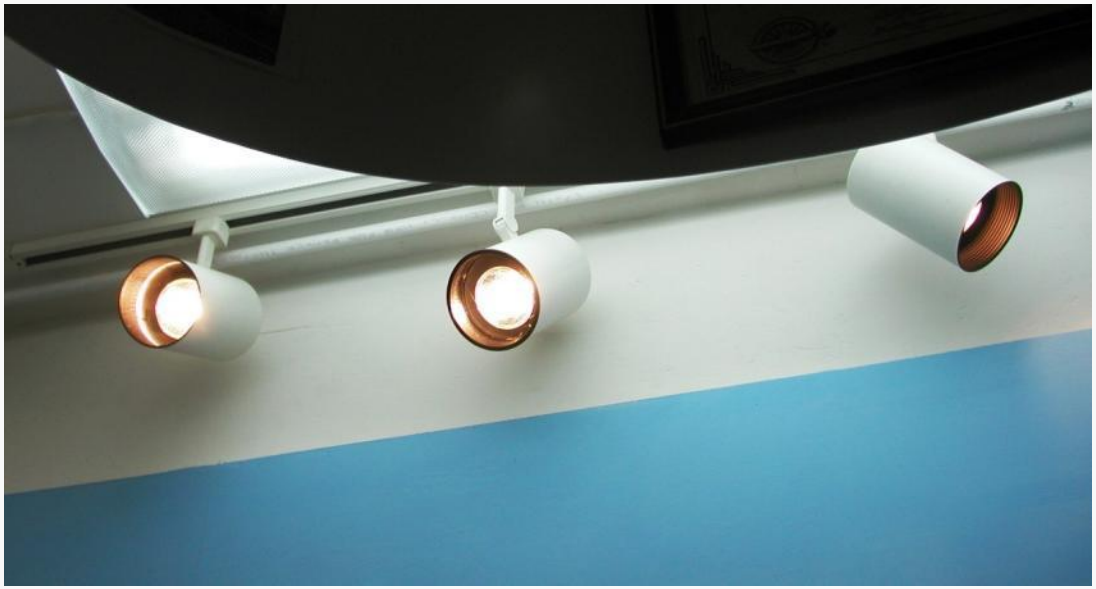
Light Sources

Two Popular Choices

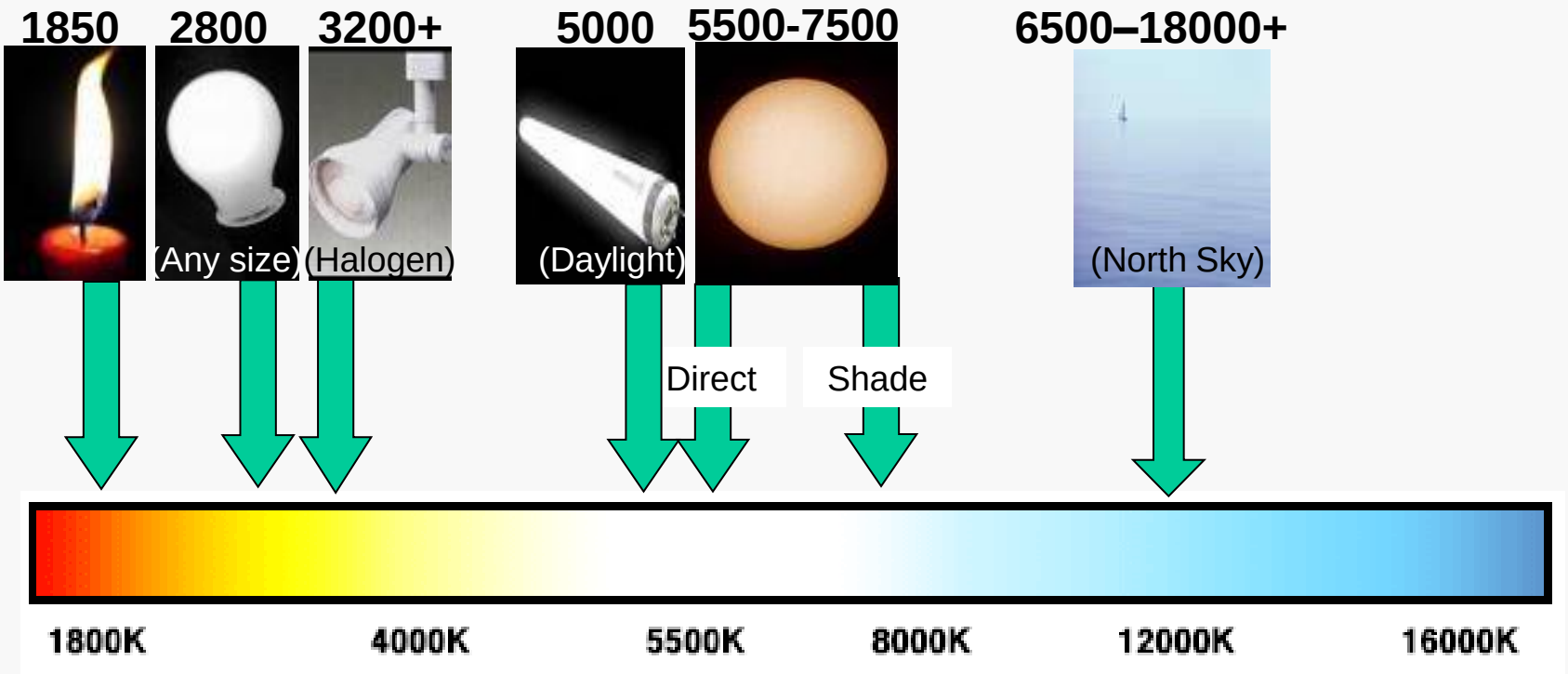
Fluorescent tubes in fittings
- High efficiency
- Dimming difficult/poor
- Careful choice needed for color temperature and CRI – *no* “cool white”
- Ultraviolet block needed

Halogen Spots on track-light fittings
- adjustable scene focus and wash
- dimmable
- more power needed

but now replaceable with low power LED’s



Color Temperatures from Various Sources



("Warm" ——— Artistic Impression ——— "Cool")

1) *Because of color peaks fluorescents are approximate e.g. "cool white" tubes @ 4100K have very high green level*
2) *Compact fluorescents are available with 5000K "daylight" color temperature – screw in replacement for incandescent lamps*
3) *LED's 3000-5000K with increasing selection.*

Lamp Characteristics 1

Conventional Lamp

14 lumens per watt

Very “orange” but can be obtained in color controlled versions

CRI =100 *(by definition)*

<u>Can</u> be dimmed.

Compact Fluorescent Lamp

62 lumens per watt

Direct replacement for incandescent at 4x efficiency

Can be obtained in color controlled versions

Lower CRI (depending on color)

<u>Cannot</u> be dimmed.

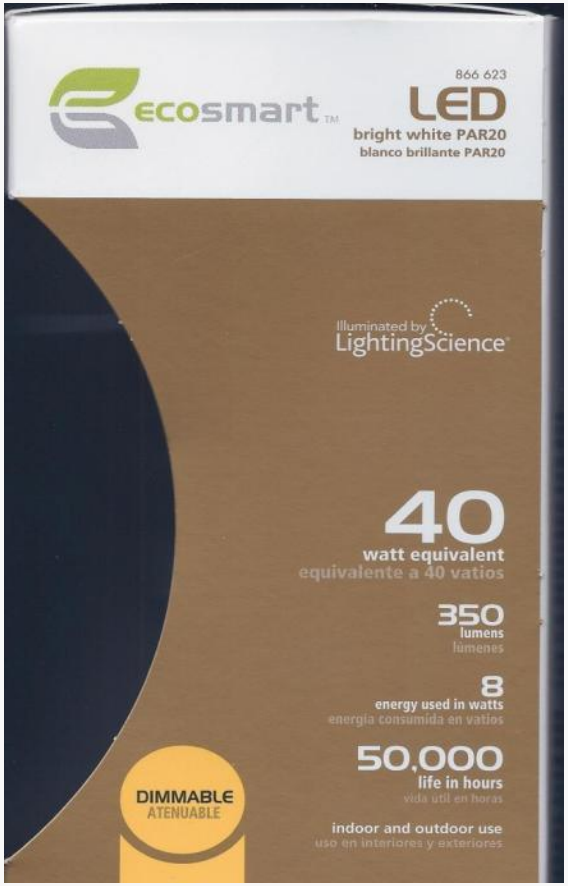
Lamp Characteristics 2

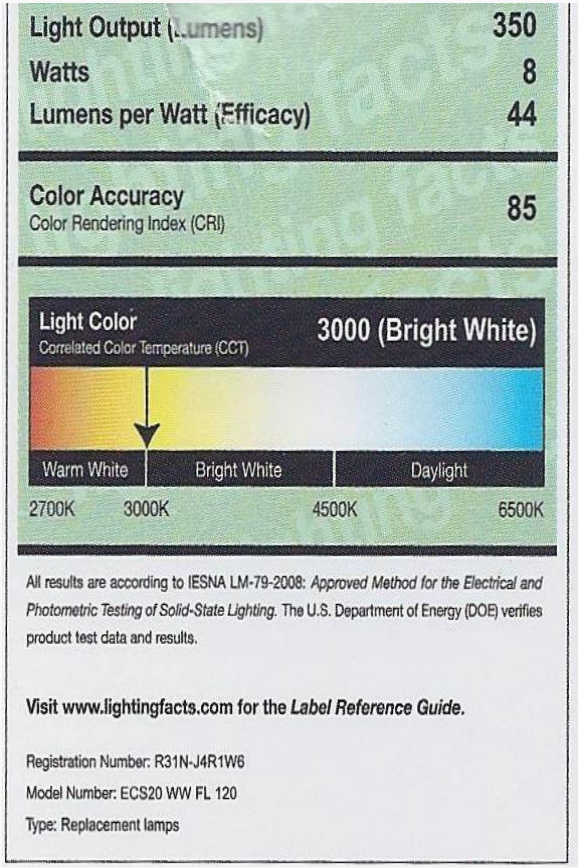
50 = watts
PAR = parabolic reflector
20 = diameter in 1/8”
CAP = manufacturer designation
NSP = narrow spot
10° = beam angle

Tungsten Halogen Spot and Flood lights

11 lumens/watt
More “white” (higher color temperature) than conventional incandescent
High CRI ~ 100
Can be dimmed
Variety of spot sizes for washing and highlighting

Lamp Characteristics 3





"watts equivalent" is becoming meaningless!

<u>You are buying lumens,</u> (even if you are paying for watts in use)

Costs

Halogen spot:
530 lumens, $6
= 90 lumens/$

This LED
350 lumens, $27
= 16 lumens/$

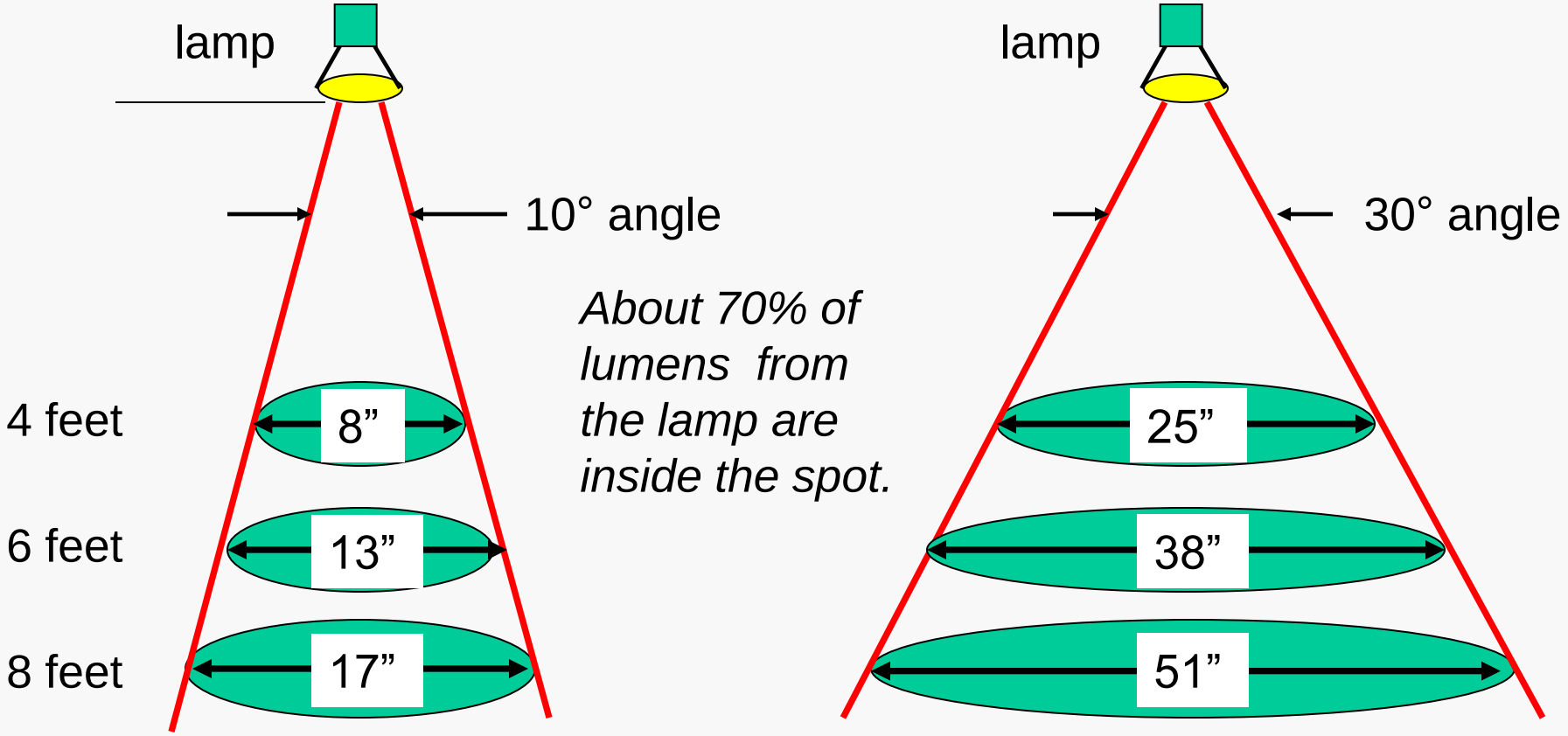
LED's will only get cheaper and better - <u>Must</u> be considered for replacements and new construction.

LED Spot and Flood Lights

44+ lumens/watt
Variety of Color Temperatures
High CRI - (*but comparison standards are still in development*)
Can be dimmed
Increasing variety of light outputs and spot sizes for washing and highlighting

Lamp Characteristics 4

Light from Spot and Flood Lights



Light Spread with Narrow Spotlight
- Structure and Scene Highlighting

Light Spread with Narrow Flood Light
- General Lighting, Large Scenes

Lamp Characteristics 5a

Fluorescent Tubes (T12)

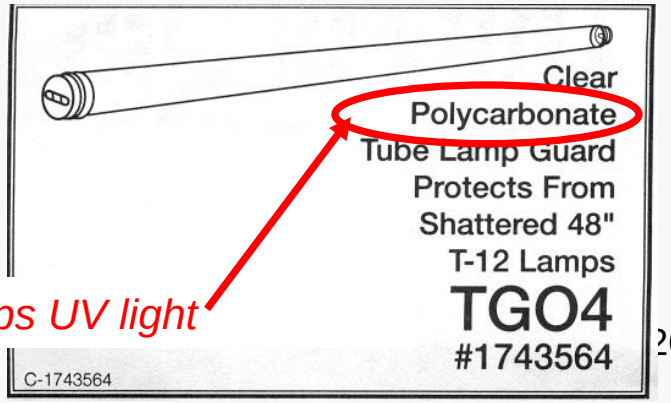
56 lumens per watt
(5 times light of 40 watt incandescent lamp)

5000K Color Temperature (recommended)
(Others available 3400K, 6500K etc.)

CRI = 90 (high)

Cannot be dimmed
(without expensive special controls.).

Use with sleeves or covers to remove ultraviolet light – prevents scenery fading



Polycarbonate stops UV light

Lamp Characteristics 5b

Other Fluorescent Tube Items

- Use electronic ballast fittings
  - Better Efficiency
  - Low audible noise
  - No visible flicker
- Use T8 Tubes (1” diameter)
  - Thinner – fit under shelves
  - Lower power (34 watts) for + 25% light output
- Effective dimming is available but needs special ballasts and wiring installation – a permanent, professional installation job.

Other Light Sources

Possibilities and Trade Offs.

- Low voltage Halogens
  - OK, but extra cost installation
  - hard to prevent glare, run very hot.
  - *LED substitutes reopen this possibility.*
- Rope Lights
  - snake under low top shelves
  - low brightness
- Christmas tree lights
  - not intended for long term use
  - too much exposed wiring
  - hard to replace

Lighting Appearance

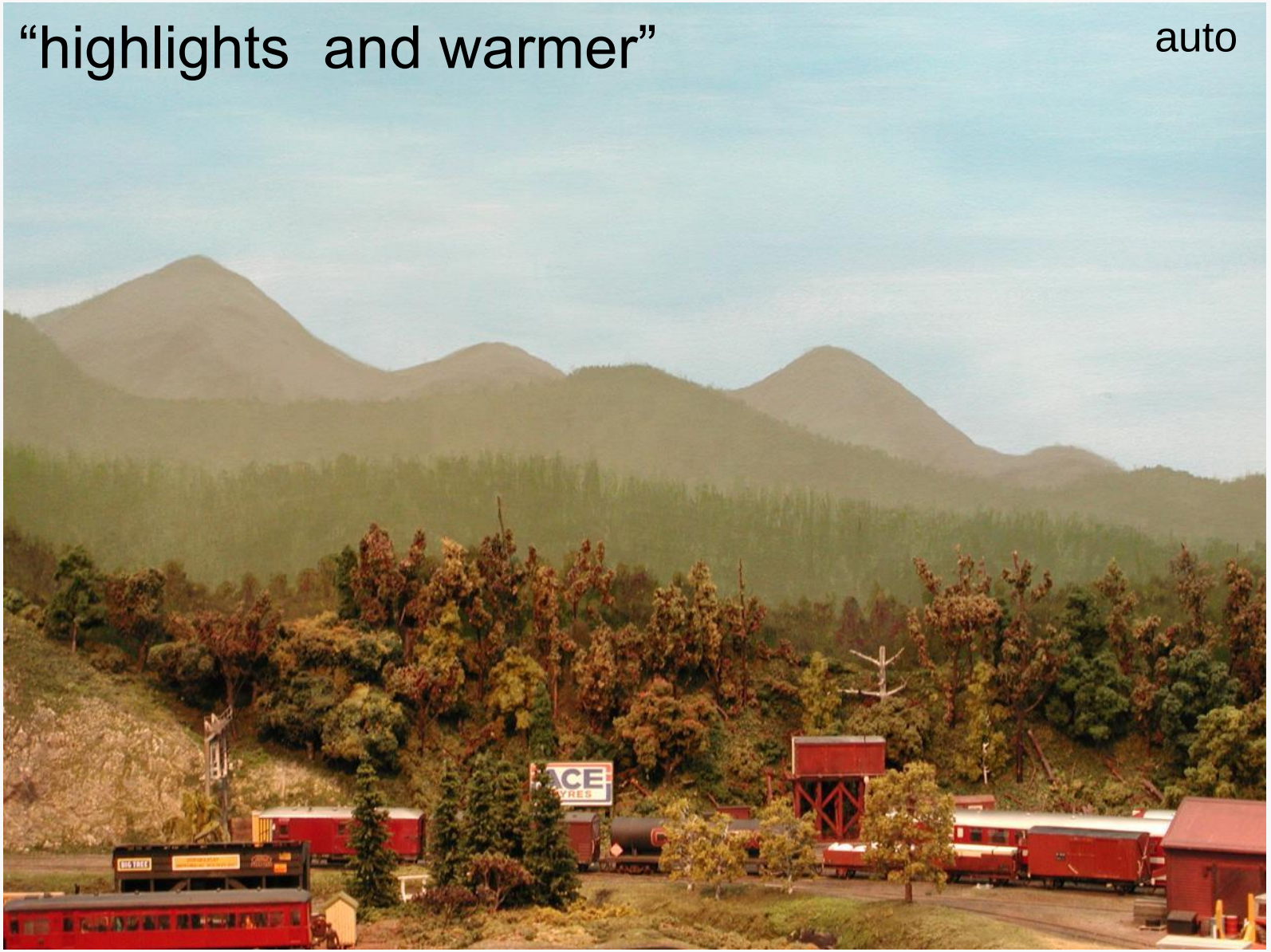
1. Daylight Fluorescents Only
2. Daylight Fluorescents + Halogen spotlights.
3. Halogen Spotlights only
4. Halogen Spotlights 50% dimmed

   - A light meter or a (digital) camera with fixed settings sees changes in illumination proportionately
   - Your eye adapts to changes and will register a 10:1 drop in illumination as only about a 50% change.
   - Camera with automatic exposure will do the same (over a range.)

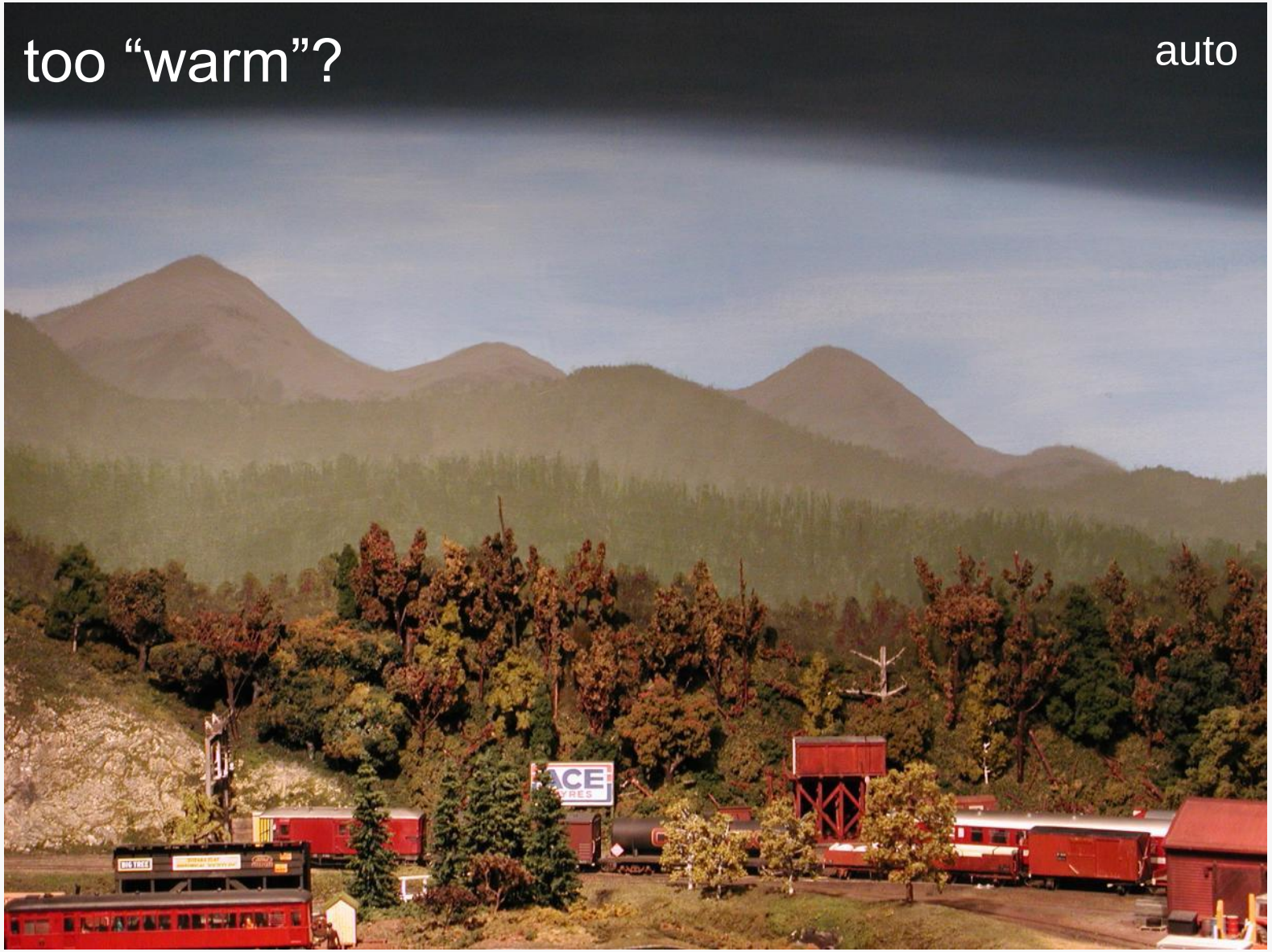
- The color appearance changes with light source
  - Fluorescents only – more white-blue (higher color temperature)
  - Halogen Spots - more red-yellow (lower color temperature)
- Fluorescent lamps only – uniform illumination - “flat” appearance
- Spotlights – directional lighting - reveal more detail in scene.

Camera: Olympus 3040, auto exposure (f 2.6, speed from 1/100 to 1/13 second)

A1: “Daylight” Fluorescent only. Illumination = 56 fc



A2: Fluorescent + Halogen Spots Illumination = 81 fc



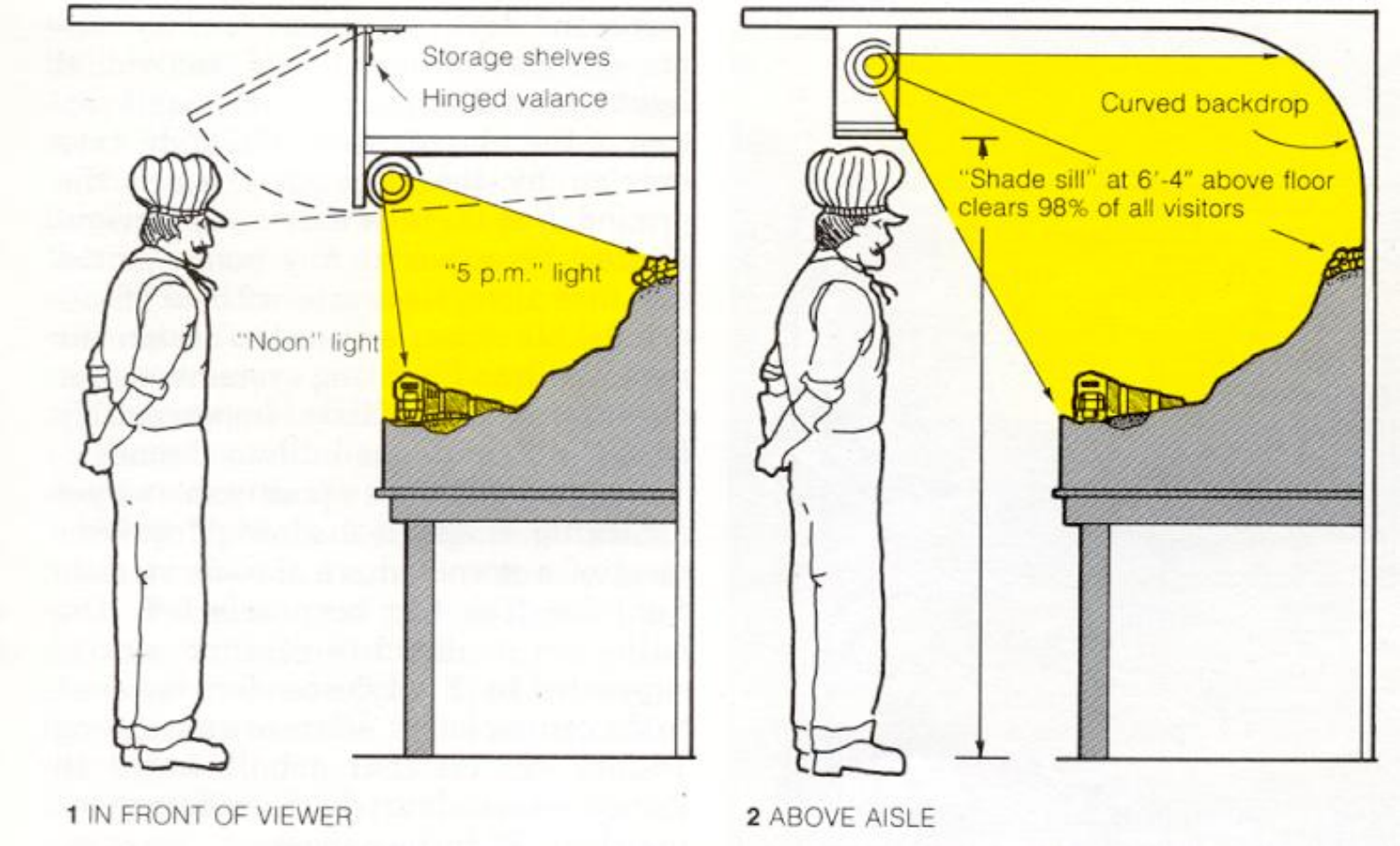
A3: Halogen Spots only. Illumination = 26 fc

A4: Halogen spots 50%. Illumination = 13 fc

Layout Installations

More Armstrong

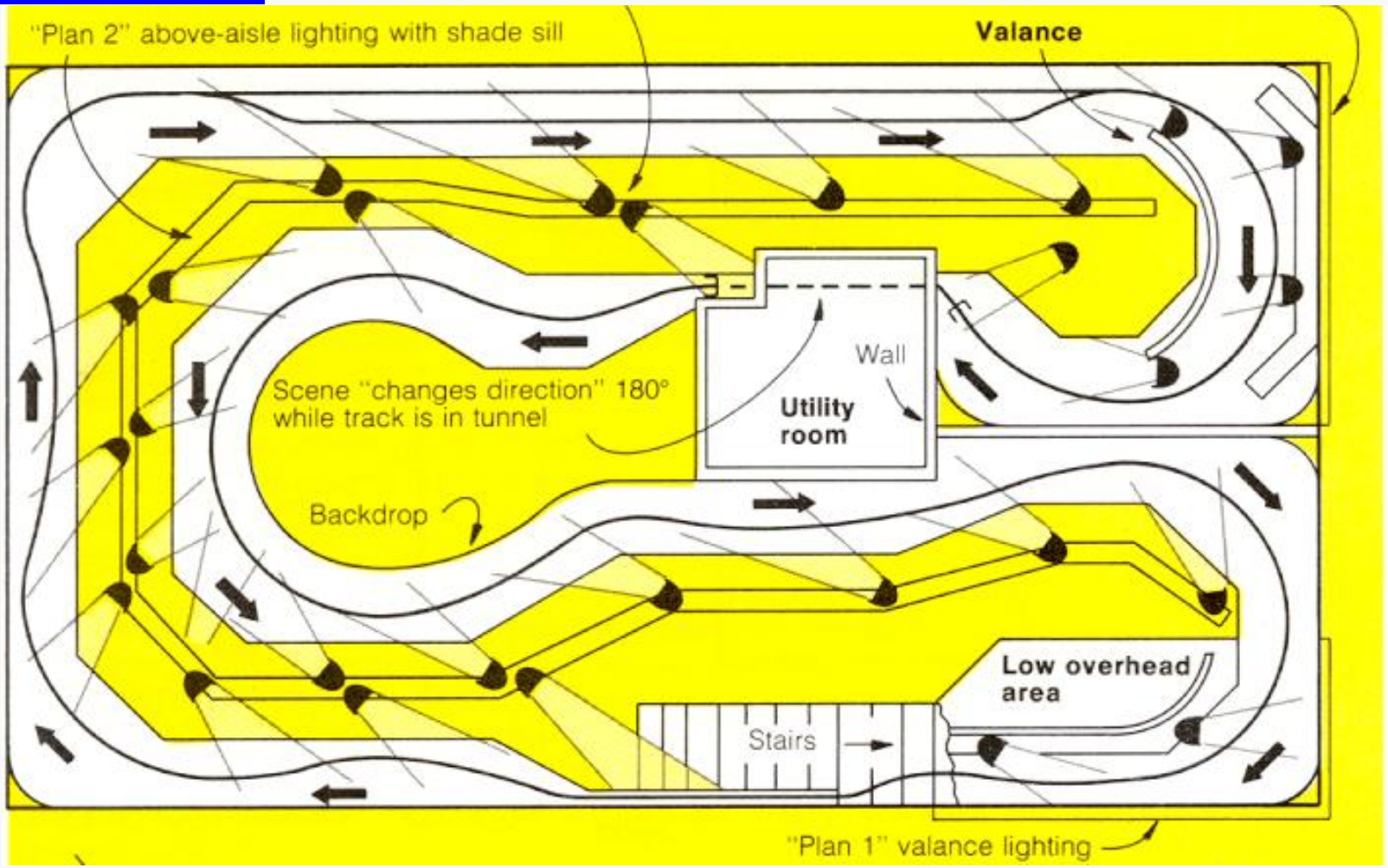
LAYOUT LIGHTING



- Keep the light sources out of your direct view
- Frame the layout like a stage setting
- Keep the aisleways dim for layout viewing and operation

From: "John Armstrong on Creative Layout Design" Kalmbach, 1978

LAYOUT LIGHTING

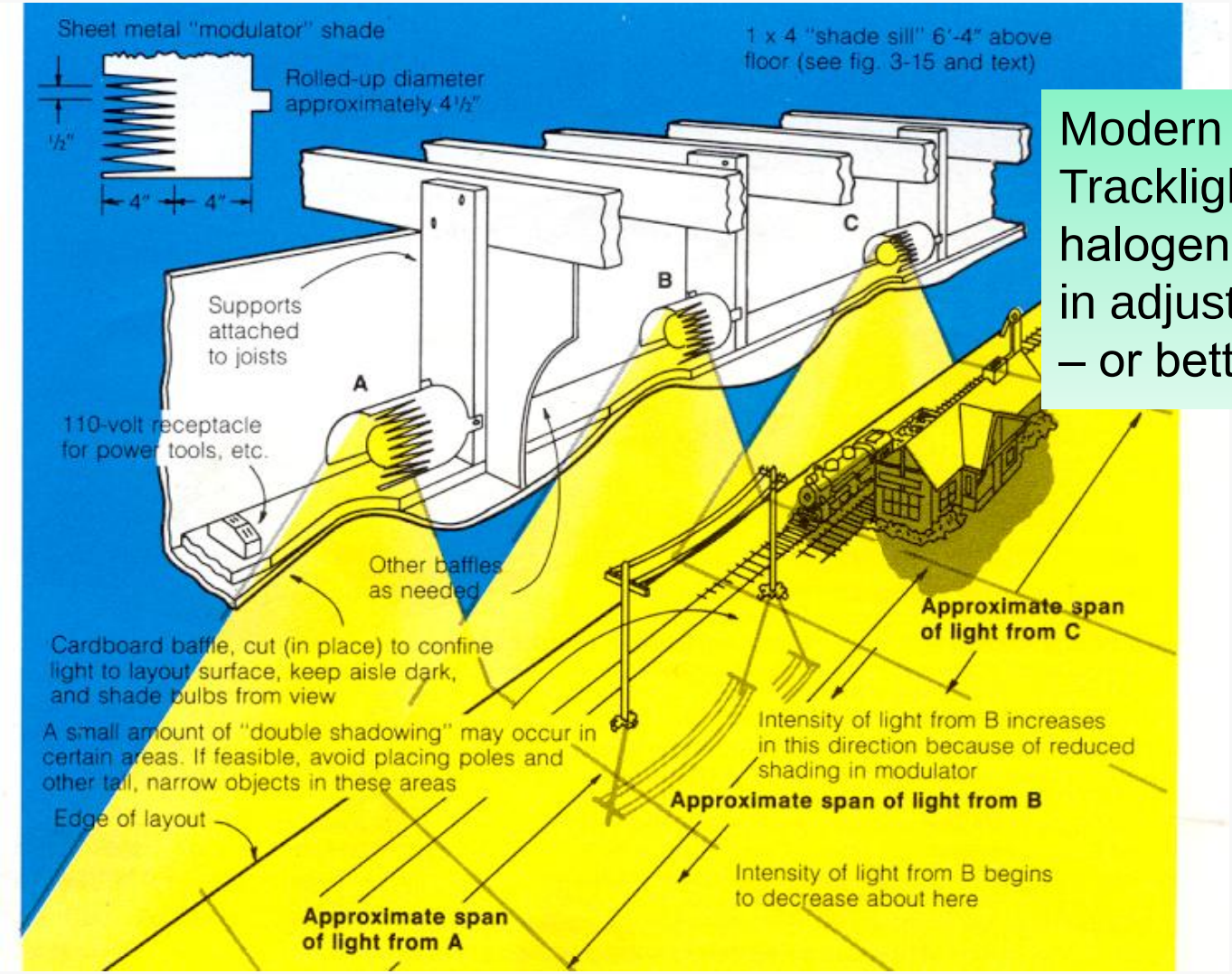


- Realistic Shadows

  When using spot or floodlights either as primary lighting or to supplement fluorescent - maintain a consistent direction of lighting relative to the track .

From: "John Armstrong on Creative Layout Design" Kalmbach, 1978

LAYOUT LIGHTING



Modern version: Tracklighting with halogen spots or CFL's in adjustable can fittings – or better yet LED's

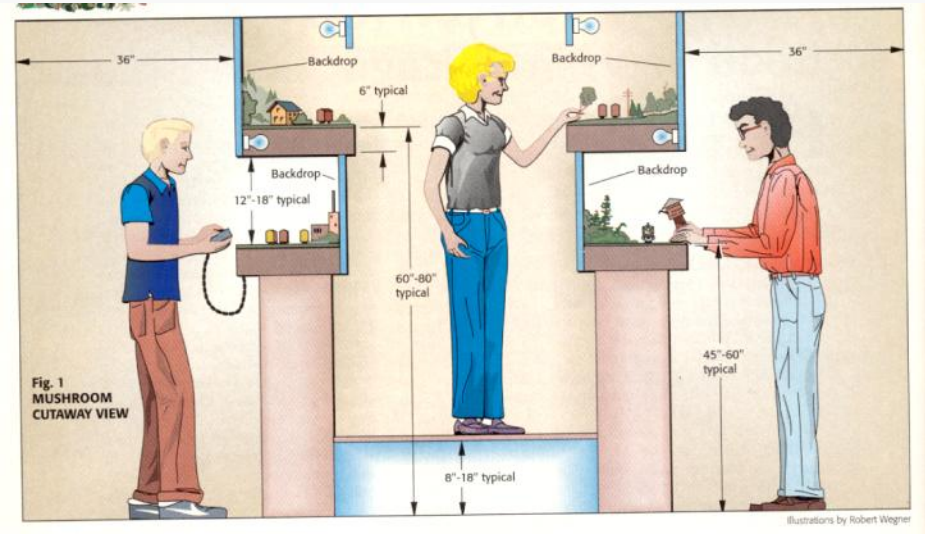
- The famous "Tin Can" light modulators with ordinary incandescent lamps.

From: "John Armstrong on Creative Layout Design" Kalmbach, 1978

Layout Installations

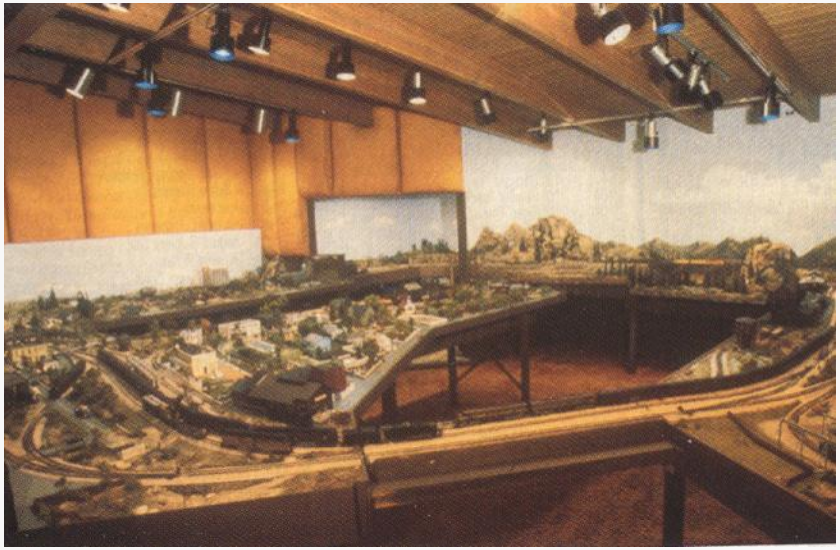
Other Approaches

LAYOUT LIGHTING



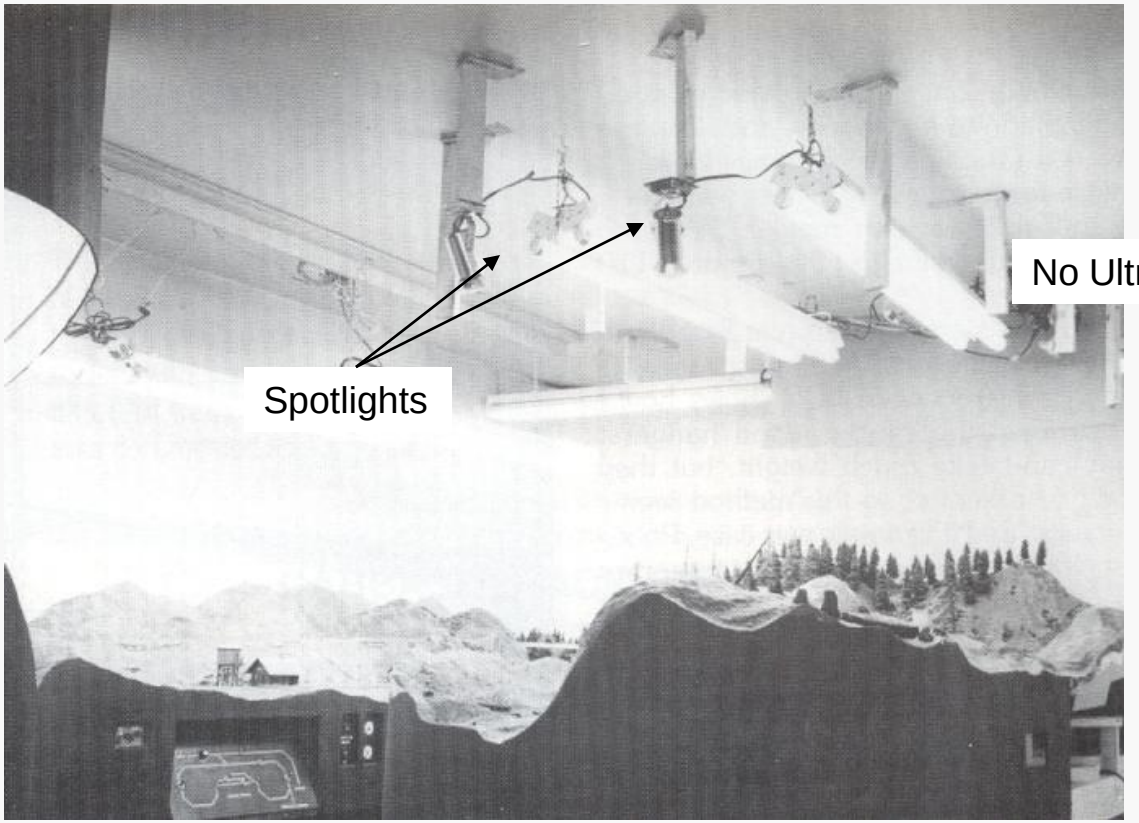
Double stacks
and
Mushrooms
- Joe Fugate

MR Jan 1997



Theatrical style lighting
MR Dec 1999 (And Tacoma Museum)

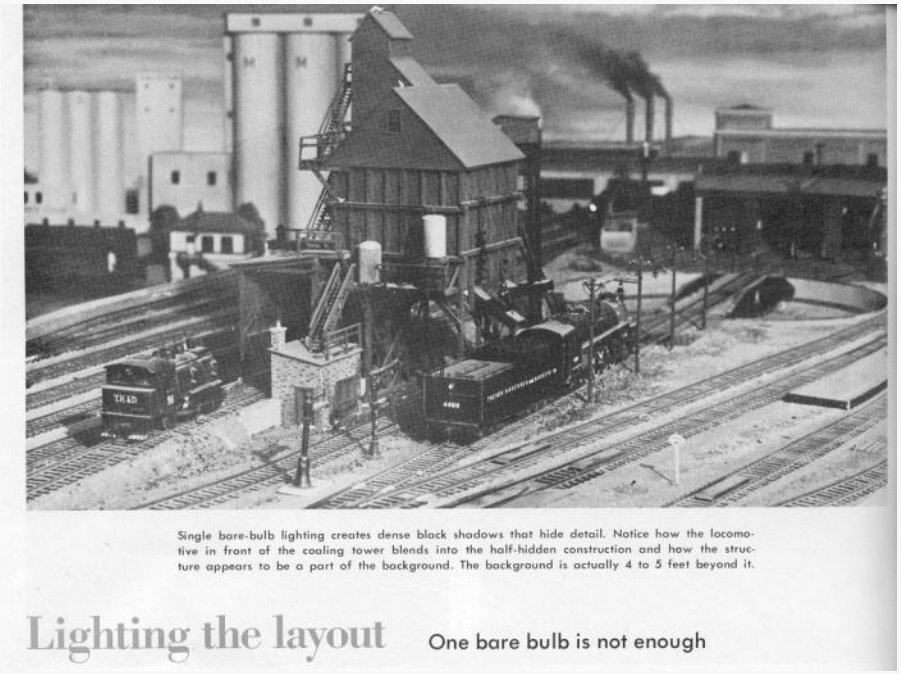
Fluorescents (pre valance)
NGSLG July/Aug 2005. Boone Morrison



You can never be bright enough !!
(valance removed)

NGSLG May/June 1997 – Boone Morrison

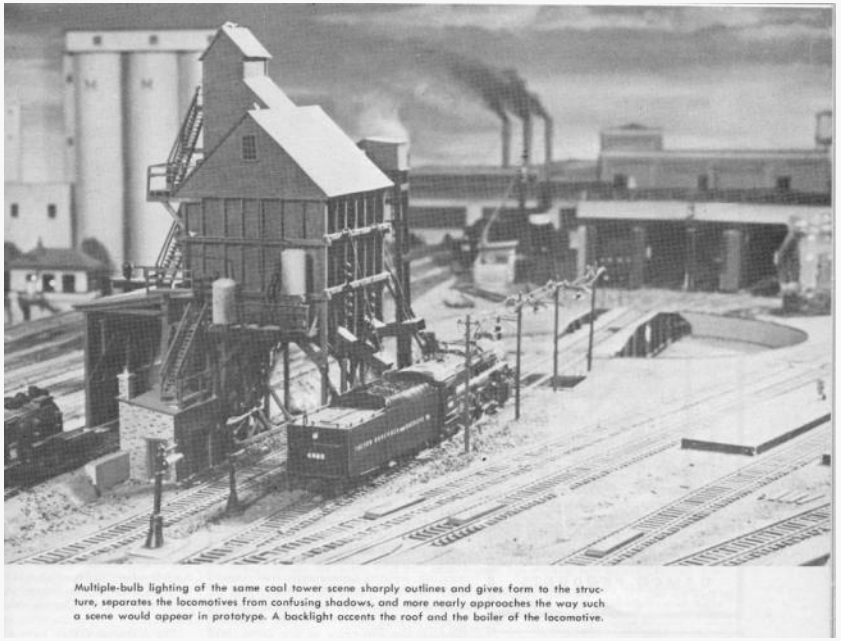
Why you need spread out light



Single bare-bulb lighting creates dense black shadows that hide detail. Notice how the locomotive in front of the coaling tower blends into the half-hidden construction and how the structure appears to be a part of the background. The background is actually 4 to 5 feet beyond it.

Lighting the layout — One bare bulb is not enough

Single light source
(or simple photoflash)

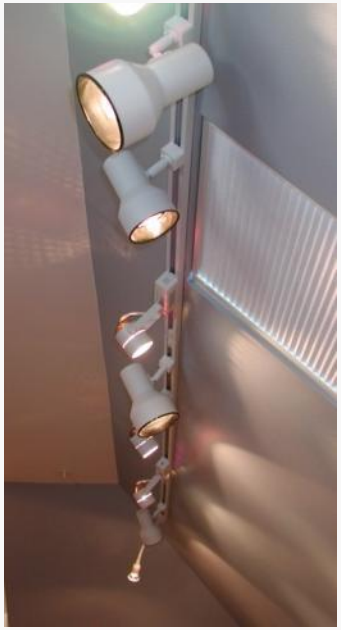


Multiple-bulb lighting of the same coal tower scene sharply outlines and gives form to the structure, separates the locomotives from confusing shadows, and more nearly approaches the way such a scene would appear in prototype. A backlight accents the roof and the boiler of the locomotive.

Distributed light source

MR November 1974 F.L. Hendren

LAYOUT LIGHTING



Tracklights R Us

Russ Segner

Fluorescents and diffuser under shelf
15 inches above layout

Al Carter

Making the best of a gap

(Thunderstorm on backdrop)

Al Carter

Stage/Diorama Setting

Darryl Huffman

Tracklights behind valance

Paul Scoles

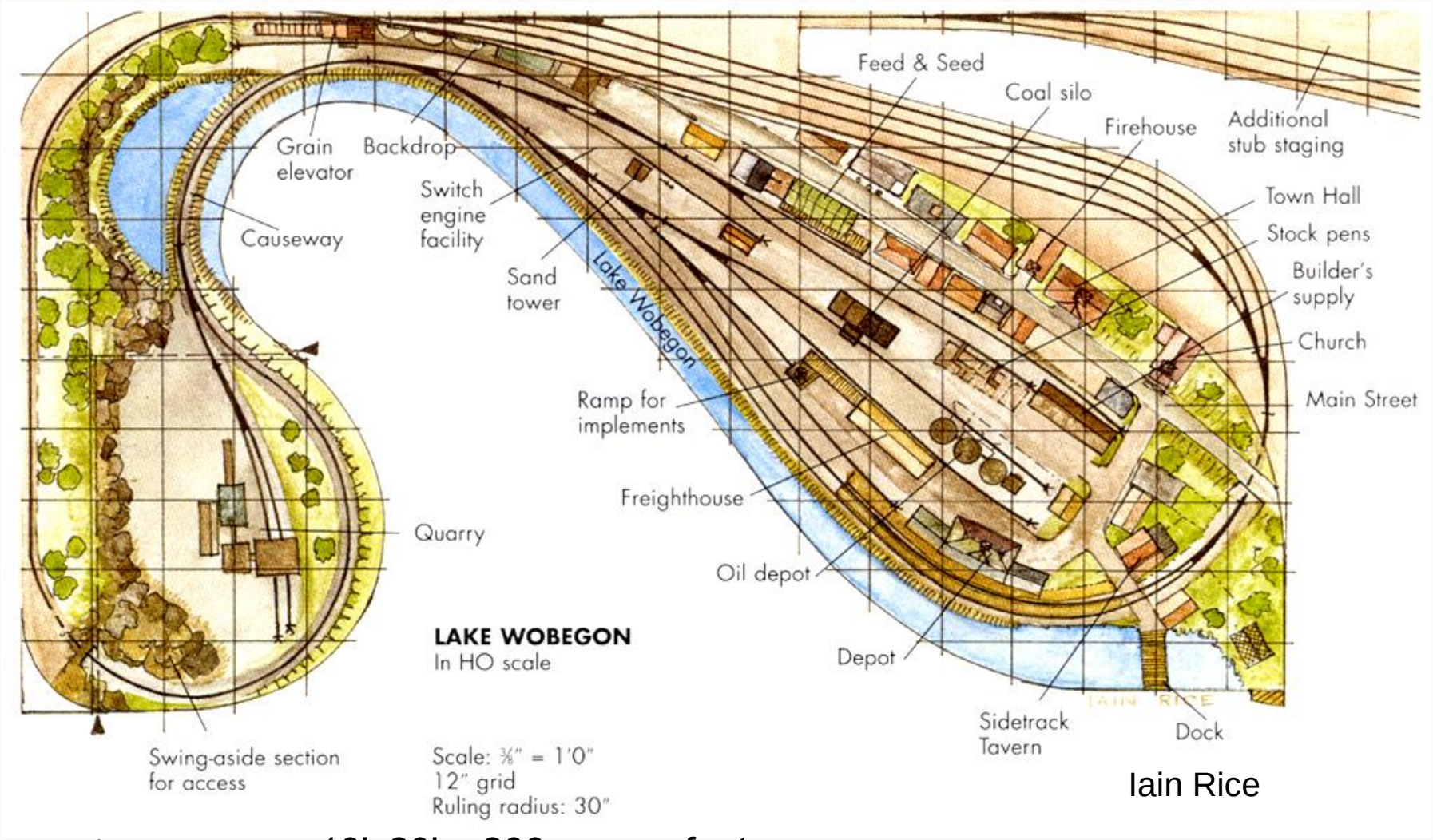
Calculating Your Requirements

Calculations

What you need

1. Drawing of layout to calculate area to be illuminated
   - Start with the top level and “helicopter view” visible area of the bottom level on multilevel layout.
   - Figure the “hidden” part of the bottom layer separately.
2. Decide on overall general light level desired – say 100 fc
3. Identify areas for special highlighting – structures, scenes etc.
4. Areas for low level lighting – aisleways, open staging.
5. List any special needs (e.g hidden staging under layout.)

Layout Example



Iain Rice

Layout room 10’x20’ = 200 square feet
Sceniced layout surface = 108 square feet
Lighting level at surface = 100 fc (say)
Total illumination needed = 108 x 100 = **10,800 lumens** for sceniced layout area.

Layout Example

How do we convert to number of lamps needed - I

- Good working assumptions and conditions for typical overall lighting arrangements:-
  - Layout is at normal desk height or above
  - **Lamps are mounted on ceiling with reflectors** so most light is directed downwards (not indirect bounce off ceiling)
  - Fluorescent lamps are behind diffusers
  - Lamps are not used enough hours per year to worry about output fading.
  - **Ceiling is white** to reflect any light going in that direction
  - **Valances are fitted (and painted white inside)**
  - Walls are mid range (backdrop)
  - General layout lighting is more or less uniform over the layout sceniced area
- Overall rule of thumb *for these assumptions and conditions* is that the "coefficient of utilization" is 50% (Scene lighting is not an exact science!)
- No valances, high or black ceilings, lights outside layout footprint etc. can reduce this to as low as 25%

Layout Example

How do we convert to number of lamps needed - II

- For 50% coefficient of utilization, we need about 22,000 lumens (2 x 10,800) rating on the light sources
- Choices:

1. T12 Fluorescent tubes 40 watts, 4' long = 2250 lumens/tube.
   10 tubes will give 22,500 lumens
   - Probably mount as 5 two tube fittings.
   - Takes 400 watts power. = *3.7 watts/sq ft of sceniced layout*

2. Incandescent lamps, 60 watt lamps = 800 lumens/lamp
   Need 27 lamps and fittings (either conventional or halogen)
   - Takes 1560 watts power = *14.5 watts/sq ft of sceniced layout.*

3. Compact Fluorescent 13 watts = 800 lumens/lamp
   Need 27 lamps and fittings
   - Takes 350 watts

4. LED's = 500 lumens/lamp *(output of LEDs' is rapidly increasing*)
   Need 44 lamps and fittings
   -- Takes ~ 450 watts

Layout Example

How do we convert to number of lamps needed- III

We have a some problems!

- With an all incandescent arrangement
  - It will be very hot in the (small) room
  - Power needed exceeds the maximum recommended load on a 15 Amp “lighting circuit”
  - There are a lot of fittings and tracks needed
  - Dimming will need at least 2 high capacity dimmers
- With an all fluorescent arrangement
  - The overall effect will be very “flat”
  - We can’t spotlight the favorite scenes
  - No dimming practical.
- With an all LED arrangement the (present) lamp cost will be > $1200

Layout Example

How do we convert to number of lamps needed - IV

Suggested solution – mix lighting types for this example layout:-

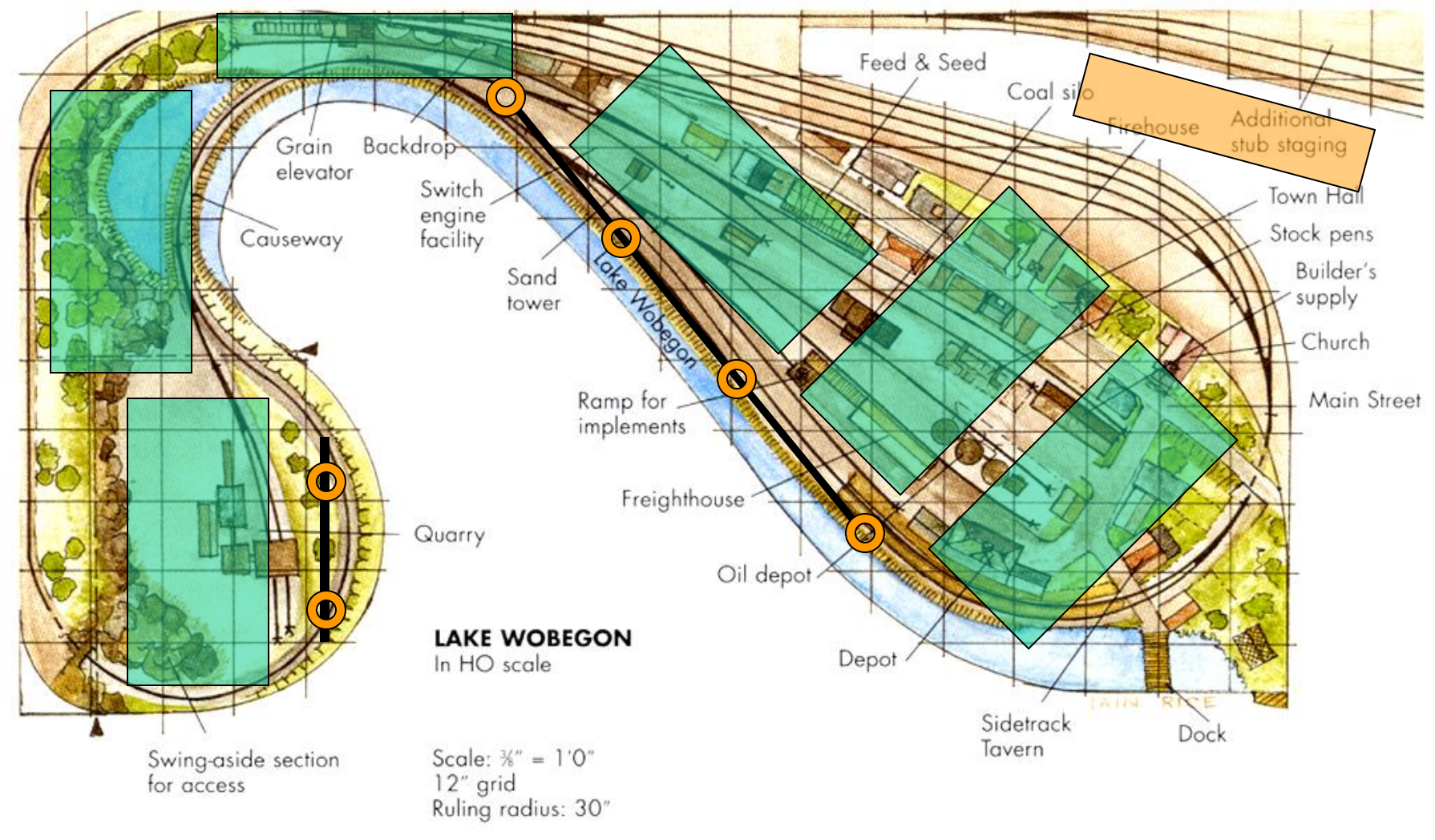
- 5 two tube fluorescent fittings distributed over the sceniced layout
  - Overall general level 100fc Power = 400 watts
  - May need to add an extra fitting to fit layout shape
  - May need to use some single tube fittings to keep behind valances.
- 6 (for example) 500 lumen spotlights on overhead tracks.
  - Additional 50fc (+/-) on selected scenes and can dim,

    Halogen spotlights, Power = 300 watts

    OR LED spotlights. Power = 75 watts
- Total power = 700 watts (halogen) ~ 6.5 watts per sq foot of layout
- Total power = 475 watts (LED) ~ 4.4 watts per sq foot of layout.

10 spotlighted scenes would raise total to 900 watts = 8.3 watts/sq ft.
or 525 watts with LED's = 4.9 watts/sq ft.

Layout - Proposed Lighting



Two tube fitting

I tube fitting

I tube fitting

spotlight

track

(add for staging if needed)

Installation Planning

Overall requirements

1. Example showed 6-8 watts per sq foot of finished layout using the fluorescent tube and halogen spotlight mix or 4-5 watts per sq ft with LED spots..

2. Having the fluorescent fittings nearly touching (or end to end on a shelf layout) is typically needed to get the required illumination.

3. Other needs
   - *Aisle ways and staging yards*
     - allow 2 watts per sq foot if this is an extensive area
     - in many cases “spillover” from layout lighting will be enough.
   - *Working light*
     - if extra lights are added for working, put them on a separate switch

4. Another approximation: if you don’t have a detail layout plan yet
   1. *For HO the layout itself will not exceed 60% of the area. (May be a little higher for a 2 level)*
   2. *For N scale assume 40%. (Relatively wider aisles)*

4. Overall planning guide (generous – especially if include LEDs’)

Allow 10 watts per square foot for the actual layout and add 10-20% for total room capacity planning.

Larger Layout Calculations

Larger Layouts

Electrical needs for good lighting can become significant .

Example: 30’ x 20’ layout = 600 sq ft

60% layout area = 360 sq ft

Electrical capacity plan (at 10 watts/sq ft) = 3600 watts + 20% = 4320 watts

This is 36 amps on 120 volt circuits.

3, 15 amp circuits will just make it, (80% loading)

4, 20 amp ones would be much better to allow for unbalanced loads, rearrangements and changes.

With the fluorescent tube/LED spot combination the capacity plan can reduce to 6 watts/sq ft = 2160 watts +20% = 2600 watts

2, circuits sufficient – *installation costs saving may pay for LED’s*

This is still way more power than anything else on your layout will ever use!

More Layout Calculations

Two layers

1. Calculate needed lamps for the top layer area + the visible (when looking from the ceiling) area of the bottom layer.
   - since the top layer is closer to the light sources and the separate bottom deck light will spill onto the exposed area you can use a larger “coefficient of utilization” – say, 60%
2. Calculate the lamps that will need to fit under the top layer to illuminate the rear part of the lower.
   - Since the distance from lamps to layout deck is usually small, (say 18 inches) use a 70% number.
3. Add together.
   - As a quick estimate, add 30% to the calculation in 1.

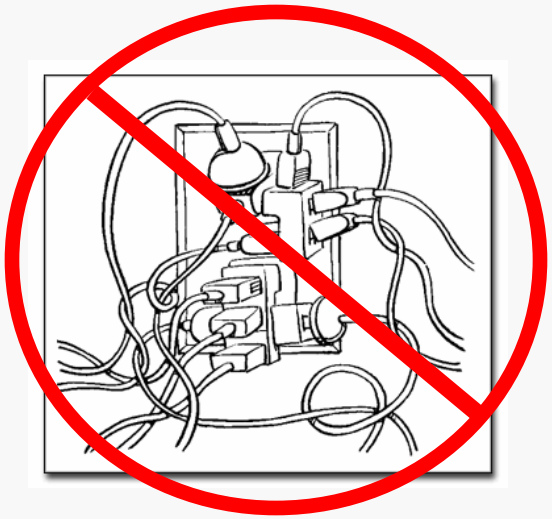
Mushroom

1. Treat as two separate layouts
2. Distance from lights to layout small for both decks, use higher coefficient of utilization
3. Use the T8 fluorescent tubes for minimum thickness

Electrical Installations

Installation: a word or two of advice!

- Be safe! its your house! No kludges!
- Run GFCI protected circuits to multiple duplex outlets on the ceiling/walls. Full code requirements!
- Allow for control zones with multiple wall switches (for fluorescents) and zone dimmers for incandescents/LEDs
- Actual lamps and tracks may be plugged into the outlets with cordsets to allow easy positioning, but no tangles!



Conclusions

1. If you can't see the models the exquisite craftsmanship is lost!
2. Layouts need to be treated like a stage setting, they need to be quite bright with no surrounding distractions.
3. Spot light the stand out scenes.
4. There is a pretty close convergence of actual lighting methods and illumination levels across "good" layouts.
5. A basic understanding of illumination and lamps is yet another skill you can acquire through model railroading!
6. Use the new skill to plan and install lights early – they are even harder than backdrops to do later.
7. In the event of PSE failures, candles won't do! (local in joke)

Planning Websites

Lighting Planning help

GE has a very useful website to calculate numbers of fluorescent fittings, spacing needed, power used etc for a required light level in “typical “ interior environments.

http://www.gelighting.com/na/business_lighting/education_resources/tools_software/toolkit/layout.htm

This will often show that getting a 100fc illumination level will require the fittings to be end to end – much as in the sample layout.