ANSI E1.48 - 2014

A Recommended Luminous Efficiency Function for Stage and Studio Luminaire Photometry

Photo/2013-5000r2

[blank page]

ANSI E1.48 - 2014

A Recommended Luminous Efficiency Function for Stage and Studio Luminaire Photometry

Photo/2013-5000r2

Approved as an American National Standard by the ANSI Board of Standards Review on 27 January 2014.

Notice and Disclaimer

ESTA does not approve, inspect, or certify any installations, procedures, equipment or materials for compliance with codes, recommended practices or standards. Compliance with an ESTA standard or recommended practice is the sole and exclusive responsibility of the manufacturer or provider and is entirely within their control and discretion. Any markings, identification, or other claims of compliance do not constitute certification or approval of any type or nature whatsoever by ESTA.

ESTA neither guarantees nor warrants the accuracy or completeness of any information published herein and disclaim liability for any personal injury, property or other damage or injury of any nature whatsoever, whether special, indirect, consequential or compensatory, directly or indirectly resulting from the publication, use of, or reliance on this document.

In issuing and distributing this document, ESTA does not either (a) undertake to render professional or other services for or on behalf of any person or entity, or (b) undertake any duty to any person or entity with respect to this document or its contents. Anyone using this document should rely on his or her own independent judgment or, as appropriate, seek the advice of a competent professional in determining the exercise of reasonable care in any given circumstance.

Published By:

Entertainment Services and Technology Association
630 Ninth Avenue, Suite 609
New York, NY 10036
USA
Phone: 1-212-244-1505
Fax: 1-212-244-1502
Email: standards@esta.org

The ESTA Technical Standards Program

The ESTA Technical Standards Program was created to serve the ESTA membership and the entertainment industry in technical standards related matters. The goal of the Program is to take a leading role regarding technology within the entertainment industry by creating recommended practices and standards, monitoring standards issues around the world on behalf of our members, and improving communications and safety within the industry. ESTA works closely with the technical standards efforts of other organizations within our industry, including USITT and VPLT, as well as representing the interests of ESTA members to ANSI, UL, and the NFPA. The Technical Standards Program is accredited by the American National Standards Institute.

The Technical Standards Council (TSC) was established to oversee and coordinate the Technical Standards Program. Made up of individuals experienced in standards-making work from throughout our industry, the Council approves all projects undertaken and assigns them to the appropriate working group. The Technical Standards Council employs a Technical Standards Manager to coordinate the work of the Council and its working groups as well as maintain a “Standards Watch” on behalf of members. Working groups include: Control Protocols, Electrical Power, Event Safety, Floors, Fog and Smoke, Followspot Position, Photometrics, Rigging, and Stage Lifts.

ESTA encourages active participation in the Technical Standards Program. There are several ways to become involved. If you would like to become a member of an existing working group, as have over four hundred people, you must complete an application which is available from the ESTA office. Your application is subject to approval by the working group and you will be required to actively participate in the work of the group. This includes responding to letter ballots and attending meetings. Membership in ESTA is not a requirement. You can also become involved by requesting that the TSC develop a standard or a recommended practice in an area of concern to you.

The Photometrics Working Group, which authored this Standard, consists of a cross section of entertainment industry professionals representing a diversity of interests. ESTA is committed to developing consensus-based standards and recommended practices in an open setting.

Contact Information

Technical Standards Manager

Karl G. Ruling
ESTA
630 Ninth Avenue, Suite 609
New York, NY 10036
USA
1-212-244-1505
karl.ruling@esta.org

Assistant Technical Standards Manager

Erin Grabe
ESTA
630 Ninth Avenue, Suite 609
New York, NY 10036
USA
1-212-244-1505
erin.grabe@esta.org

Technical Standards Council Chairpersons

Mike Garl
Mike Garl Consulting LLC
1-865-389-4371
mike@mikegarlconsulting.com

Mike Wood
Mike Wood Consulting LLC
1-512-288-4916
mike@mikewoodconsulting.com

Photometrics Working Group Chairperson

Jerry Gorrell
Theatre Safety Programs
1-480-837-9401
jerryg@jgorrell.com

Acknowledgments

The Photometrics Working Group members when this document was approved by the working group on 4 December 2013 are shown below.

Voting members:

Jerry Gorrell; Theatre Safety Programs; U
Jefferey Knox; Schuler Shook; DE
Michael Lay; Royal Philips; MP
Kimberly Corbett Oates; Schuler Shook; DE
Mark Ravenhill; GLP German Light Products GmbH; MP
Karl G. Ruling; Unit 12 Productions; DE
Markus Salm; GLP German Light Products GmbH; MP
Ken Vannice; Ken Vannice LLC; G
Mike Wagner; Arnold & Richter Cine Technik; MP
Mike Wood; Mike Wood Consulting LLC; G

Observer (non-voting) members:

Robert Barbagallo; Solotech Inc.; DR
Mosè Benaglia; Clay Paky S.P.A.; MP
David Bertenshaw; G
Lee J. Bloch; Bloch Design Group, Inc.; U
Ron Bonner; PLASA EU; G
André Broucke; G
Jeremy Day; Royal Philips; MP
Bill Ellis; Candela Controls, Inc.; U
Gregg Esakoff; Electronic Theatre Controls, Inc.; MP
Charles H. Green; Charles H. Green; U
Tim Hansen; Oasis Stage Werks; U
Mitch Hefter; G
A C Hickox; Domingo Gonzalez Associates; U
Ed Hyatt; Boston Illumination Group; CP
Joseph M. Good_III; Spectrum Professional Services; G
Dennis Thykjær Jørgensen; Martin Professional A/S; MP
Francois Juliat; Robert Juliat; MP
Hiroshi Kita; Marumo Electric Co., Ltd.; MP
Bill Klages; New Klages Inc.; U
Larry Lieberman; Vision Quest Lighting; CP
Rick Loudenburg; Barbizon Companies; DR
Doug MacDonald; Designlab Chicago Inc.; DR
Jim McHugh; Humboldt State University; U
John T. Ryan; Altman Stage Lighting; MP
Ron Rykowski; Radiant Imaging, Inc.; G
Robert Timmerman; Royal Philips; MP
Garrett Young; Prism Projection, Inc.; MP

Interest category codes:

CP = custom-market producer
DR = dealer rental company
MP = mass-market producer
DE = designer
G = general interest
U = user

Table of contents

Table of contents v
1 Introduction (not normative) 1
1.1 Problem 1
1.2 Background 1
1.3 Solution 2
2 Scope (normative) 2
3 Requirements (normative) 3
3.1 Measurement 3
3.2 Reporting V(λ) 7

1 Introduction (not normative)

1.1 Problem

The problem this Standard attempts to address is that many light meters, whether hand-held or part of a goniophotometer or other apparatus, use a photopic luminous efficiency function, V(λ), that does not accurately match the response of the human eye. They give meter readings for stage and studio luminaires with significant extreme blue and red output as having lower luminous output than they appear to have to the human viewer. Therefore, we recommend a luminosity efficiency function that more closely approximates the response of the human eye for use with meters measuring the illuminance of stage and studio luminaires.

1.2 Background

Quite often the photopic luminous efficiency function, V(λ), used by light meters is the one commonly called "CIE 1924," which is, as the name suggests, more than 80 years old. There also are more recent luminosity functions, such as CIE 2004, published in ISO 23539:2005(E), Photometry - The CIE System Of Physical Photometry, which is cited by IES LM-79-08, Approved Method for the Electrical and Photometric Measurements of Solid-State Lighting Products. However, even this most recent standard for the photopic luminous efficiency function does not agree with the most recent published research on the human perception of light as a function of wavelength. This disagreement can lead to low meter readings—readings that do not match what a person's eyes are telling him when he looks at the output of a stage and studio luminaire.

The error is small with continuous spectrum sources such as incandescent lamps when producing nominally white light, but the error can be significant with luminaires that use narrow-band sources or that use filters on continuous spectrum white sources to produce intensely colored light. For example, a luminaire using red, green, and blue LEDs with outputs centered at 660, 525, and 470 nm will have the output of the red and blue LEDs under-reported by 11% and 47% per CIE 1924 and by 9% and 43% per CIE 2004 compared to the V(λ) function recommended in this Standard. In both cases, these differences are significant. An error also will be found with heavily filtered output from a continuous source. The transmission through a congo blue gel will be almost entirely above 660 nm and below 500 nm, which are the extreme ends of the spectrum where CIE 1924 and CIE 2004 most deviate from the V(λ) function recommended here. Figure 1 shows the CIE 1924 function and the V(λ) function recommended in this Standard. The increased sensitivity with this Standard's function can be seen clearly.

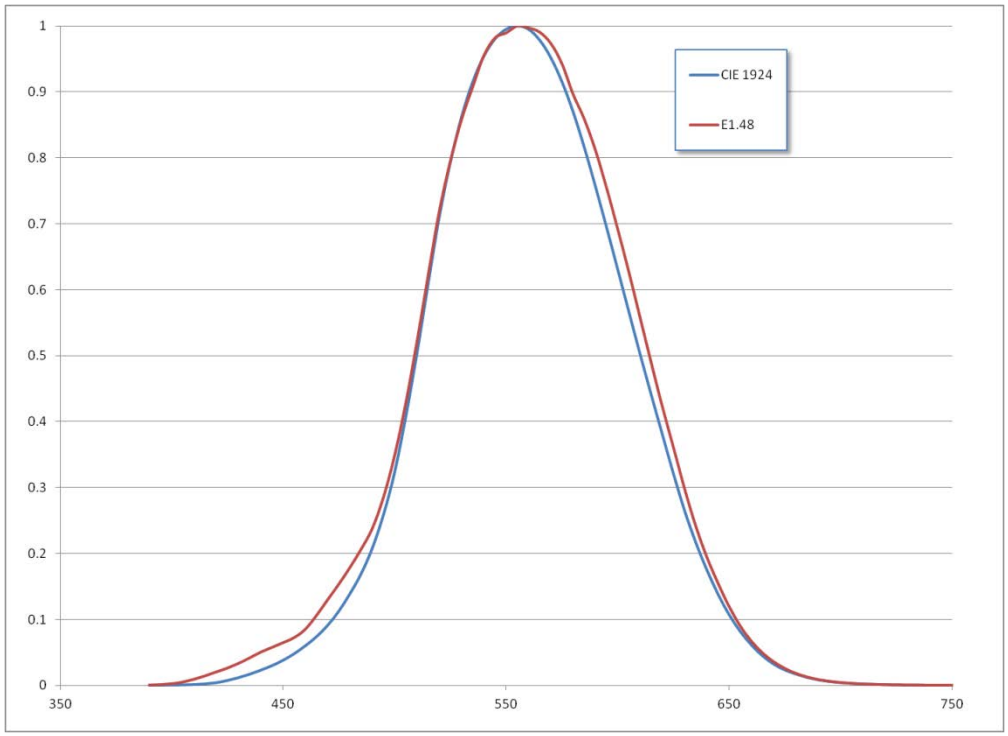

Figure 1

Industries that use primarily white light from continuous or near-continuous sources are perhaps not materially affected by the inaccurate V(λ) functions embodied in common light meters. However, the entertainment industry, which uses narrow-band emitters and intensely colored light, is seriously affected. Published luminaire performance data can be off by 50%, simply because the meters used to measure the light output conformed to an inaccurate photopic luminous efficiency function.

Photometry differs from most other measurement sciences in that nothing is absolute, instead everything is referred back to the human eye and the theoretical "standard observer." You can't have a standard lumen in quite the same way as you have a standard kilogram or a standard metre, Instead, the standards are based on statistical studies of many people in an attempt to produce an acceptable average for human vision. The photopic luminous efficiency function, V(λ), is a means of presenting the data from that accepted average standard observer in a usable form. Most light meters are designed to mimic the response of the human eye, not that of a video camera or other light sensor.

1.3 Solution

The solution we propose is to specifically recommend the use of a photopic luminous efficiency function, V(λ), that better matches the response of the human eye than the common historical V(λ) function, when measuring the output of stage and studio luminaires, particularly when measuring those for which it is known or believed that 20% or more of the output power is at wavelengths shorter than 500 nm.

The photopic luminous efficiency function, V(λ), specified here is based on research done with human subjects in the last decade. It has been offered to the CIE (Commission Internationale de l'Éclairage) for adoption as an international standard, but that adoption is still pending as this E1.48 standard is being written.

2 Scope (normative)

This Standard shall apply to all stage and studio luminaires, but particularly to those for which it is known or believed that 20% or more of the output power is at wavelengths shorter than 500 nm.

3 Requirements (normative)

3.1 Measurement

Meters of any type that measure the output of a stage or studio luminaire shall have a photopic luminous efficiency function, V(λ), that matches the values given in the following table:

Luminous Efficiency Function V(λ)

λ nm	V	λ nm	V	λ nm	V
390	4.14616E-04	422	2.26004E-02	454	7.06328E-02
391	5.02833E-04	423	2.37479E-02	455	7.23834E-02
392	6.08499E-04	424	2.49125E-02	456	7.43596E-02
393	7.34444E-04	425	2.61211E-02	457	7.65938E-02
394	8.83739E-04	426	2.73992E-02	458	7.91144E-02
395	1.05965E-03	427	2.87499E-02	459	8.19535E-02
396	1.26553E-03	428	3.01691E-02	460	8.51482E-02
397	1.50475E-03	429	3.16514E-02	461	8.87266E-02
398	1.78049E-03	430	3.31904E-02	462	9.26601E-02
399	2.09557E-03	431	3.47791E-02	463	9.68972E-02
400	2.45219E-03	432	3.64149E-02	464	1.01375E-01
401	2.85222E-03	433	3.80957E-02	465	1.06014E-01
402	3.29912E-03	434	3.98184E-02	466	1.10738E-01
403	3.79747E-03	435	4.15794E-02	467	1.15511E-01
404	4.35277E-03	436	4.33710E-02	468	1.20312E-01
405	4.97172E-03	437	4.51718E-02	469	1.25116E-01
406	5.66101E-03	438	4.69542E-02	470	1.29896E-01
407	6.42161E-03	439	4.86872E-02	471	1.34630E-01
408	7.25031E-03	440	5.03366E-02	472	1.39331E-01
409	8.14017E-03	441	5.18761E-02	473	1.44023E-01
410	9.07986E-03	442	5.33222E-02	474	1.48737E-01
411	1.00561E-02	443	5.47060E-02	475	1.53507E-01
412	1.10646E-02	444	5.60634E-02	476	1.58364E-01
413	1.21052E-02	445	5.74339E-02	477	1.63320E-01
414	1.31801E-02	446	5.88511E-02	478	1.68376E-01
415	1.42938E-02	447	6.03081E-02	479	1.73537E-01
416	1.54500E-02	448	6.17864E-02	480	1.78805E-01
417	1.66409E-02	449	6.32657E-02	481	1.84182E-01
418	1.78530E-02	450	6.47235E-02	482	1.89656E-01
419	1.90702E-02	451	6.61475E-02	483	1.95210E-01
420	2.02737E-02	452	6.75726E-02	484	2.00826E-01
421	2.14481E-02	453	6.90493E-02	485	2.06483E-01

λ nm	V
486	2.12183E-01
487	2.18028E-01
488	2.24159E-01
489	2.30730E-01
490	2.37916E-01
491	2.45871E-01
492	2.54602E-01
493	2.64076E-01
494	2.74249E-01
495	2.85068E-01
496	2.96484E-01
497	3.08501E-01
498	3.21139E-01
499	3.34418E-01
500	3.48354E-01
501	3.62960E-01
502	3.78228E-01
503	3.94136E-01
504	4.10658E-01
505	4.27760E-01
506	4.45399E-01
507	4.63540E-01
508	4.82138E-01
509	5.01143E-01
510	5.20497E-01
511	5.40139E-01
512	5.60021E-01
513	5.80097E-01
514	6.00317E-01
515	6.20626E-01
516	6.40940E-01
517	6.61077E-01
518	6.80813E-01
519	6.99904E-01
520	7.18089E-01
521	7.35159E-01
522	7.51182E-01

λ nm	V
523	7.66314E-01
524	7.80735E-01
525	7.94645E-01
526	8.08207E-01
527	8.21382E-01
528	8.34070E-01
529	8.46171E-01
530	8.57580E-01
531	8.68241E-01
532	8.78306E-01
533	8.87991E-01
534	8.97521E-01
535	9.07135E-01
536	9.16995E-01
537	9.26929E-01
538	9.36673E-01
539	9.45948E-01
540	9.54468E-01
541	9.61983E-01
542	9.68439E-01
543	9.73829E-01
544	9.78152E-01
545	9.81411E-01
546	9.83667E-01
547	9.85208E-01
548	9.86381E-01
549	9.87536E-01
550	9.89023E-01
551	9.91081E-01
552	9.93491E-01
553	9.95917E-01
554	9.98021E-01
555	9.99461E-01
556	9.99993E-01
557	9.99756E-01
558	9.98984E-01
559	9.97912E-01

λ nm	V
560	9.96774E-01
561	9.95736E-01
562	9.94711E-01
563	9.93553E-01
564	9.92116E-01
565	9.90255E-01
566	9.87860E-01
567	9.84932E-01
568	9.81504E-01
569	9.77603E-01
570	9.73261E-01
571	9.68476E-01
572	9.63137E-01
573	9.57106E-01
574	9.50254E-01
575	9.42457E-01
576	9.33690E-01
577	9.24289E-01
578	9.14671E-01
579	9.05233E-01
580	8.96361E-01
581	8.88307E-01
582	8.80846E-01
583	8.73645E-01
584	8.66376E-01
585	8.58720E-01
586	8.50430E-01
587	8.41505E-01
588	8.32011E-01
589	8.22015E-01
590	8.11587E-01
591	8.00787E-01
592	7.89652E-01
593	7.78205E-01
594	7.66473E-01
595	7.54479E-01
596	7.42247E-01

λ nm	V
597	7.29823E-01
598	7.17252E-01
599	7.04582E-01
600	6.91855E-01
601	6.79101E-01
602	6.66285E-01
603	6.53359E-01
604	6.40281E-01
605	6.27007E-01
606	6.13515E-01
607	5.99849E-01
608	5.86068E-01
609	5.72226E-01
610	5.58375E-01
611	5.44554E-01
612	5.30767E-01
613	5.17013E-01
614	5.03289E-01
615	4.89595E-01
616	4.75944E-01
617	4.62396E-01
618	4.49015E-01
619	4.35862E-01
620	4.22990E-01
621	4.10415E-01
622	3.98036E-01
623	3.85730E-01
624	3.73391E-01
625	3.60924E-01
626	3.48286E-01
627	3.35570E-01
628	3.22896E-01
629	3.10370E-01
630	2.98086E-01
631	2.86116E-01
632	2.74482E-01
633	2.63195E-01

λ nm	V
634	2.52263E-01
635	2.41690E-01
636	2.31481E-01
637	2.21638E-01
638	2.12162E-01
639	2.03054E-01
640	1.94312E-01
641	1.85923E-01
642	1.77827E-01
643	1.69965E-01
644	1.62284E-01
645	1.54740E-01
646	1.47308E-01
647	1.40017E-01
648	1.32901E-01
649	1.25991E-01
650	1.19312E-01
651	1.12882E-01
652	1.06711E-01
653	1.00805E-01
654	9.51665E-02
655	8.97959E-02
656	8.46904E-02
657	7.98401E-02
658	7.52337E-02
659	7.08606E-02
660	6.67104E-02
661	6.27736E-02
662	5.90418E-02
663	5.55070E-02
664	5.21614E-02
665	4.89970E-02
666	4.60058E-02
667	4.31788E-02
668	4.05075E-02
669	3.79838E-02
670	3.55998E-02

λ nm	V
671	3.33486E-02
672	3.12233E-02
673	2.92178E-02
674	2.73260E-02
675	2.55422E-02
676	2.38612E-02
677	2.22786E-02
678	2.07902E-02
679	1.93919E-02
680	1.80794E-02
681	1.68482E-02
682	1.56919E-02
683	1.46045E-02
684	1.35806E-02
685	1.26157E-02
686	1.17070E-02
687	1.08561E-02
688	1.00648E-02
689	9.33338E-03
690	8.66128E-03
691	8.04605E-03
692	7.48113E-03
693	6.95999E-03
694	6.47707E-03
695	6.02768E-03
696	5.60817E-03
697	5.21669E-03
698	4.85179E-03
699	4.51201E-03
700	4.19594E-03
701	3.90206E-03
702	3.62837E-03
703	3.37301E-03
704	3.13432E-03
705	2.91086E-03
706	2.70153E-03
707	2.50580E-03

λ nm	V
708	2.32323E-03
709	2.15333E-03
710	1.99556E-03
711	1.84932E-03
712	1.71398E-03
713	1.58890E-03
714	1.47345E-03
715	1.36702E-03
716	1.26895E-03
717	1.17842E-03
718	1.09464E-03
719	1.01694E-03
720	9.44727E-04
721	8.77517E-04
722	8.15044E-04
723	7.57076E-04
724	7.03376E-04
725	6.53705E-04
726	6.07805E-04
727	5.65344E-04
728	5.26005E-04
729	4.89506E-04
730	4.55597E-04
731	4.24055E-04
732	3.94686E-04
733	3.67318E-04
734	3.41794E-04
735	3.17974E-04
736	2.95744E-04
737	2.75056E-04
738	2.55864E-04
739	2.38114E-04
740	2.21745E-04
741	2.06671E-04
742	1.92747E-04
743	1.79831E-04
744	1.67802E-04

λ nm	V
745	1.56557E-04
746	1.46017E-04
747	1.36153E-04
748	1.26945E-04
749	1.18367E-04
750	1.10393E-04
751	1.02991E-04
752	9.61184E-05
753	8.97332E-05
754	8.37969E-05
755	7.82744E-05
756	7.31331E-05
757	6.83414E-05
758	6.38704E-05
759	5.96939E-05
760	5.57886E-05
761	5.21351E-05
762	4.87218E-05
763	4.55385E-05
764	4.25744E-05
765	3.98188E-05
766	3.72588E-05
767	3.48747E-05
768	3.26477E-05
769	3.05614E-05
770	2.86018E-05
771	2.67584E-05
772	2.50294E-05
773	2.34137E-05
774	2.19091E-05
775	2.05126E-05
776	1.92190E-05
777	1.80180E-05
778	1.68990E-05
779	1.58531E-05
780	1.48724E-05
781	1.39509E-05

λ nm	V
782	1.30853E-05
783	1.22733E-05
784	1.15123E-05
785	1.08000E-05
786	1.01336E-05
787	9.50992E-06
788	8.92563E-06
789	8.37785E-06
790	7.86392E-06
791	7.38154E-06
792	6.92910E-06
793	6.50514E-06
794	6.10822E-06
795	5.73694E-06
796	5.38983E-06
797	5.06527E-06
798	4.76167E-06
799	4.47756E-06
800	4.21160E-06
801	3.96246E-06
802	3.72867E-06
803	3.50888E-06
804	3.30187E-06
805	3.10656E-06
806	2.92212E-06
807	2.74821E-06
808	2.58456E-06
809	2.43087E-06
810	2.28679E-06
811	2.15191E-06
812	2.02566E-06
813	1.90746E-06
814	1.79679E-06
815	1.69315E-06
816	1.59603E-06
817	1.50490E-06
818	1.41925E-06

λ nm	V
819	1.33860E-06
820	1.26256E-06
821	1.19077E-06
822	1.12303E-06

λ nm	V
823	1.05915E-06
824	9.98951E-07
825	9.42251E-07
826	8.88880E-07

λ nm	V
827	8.38669E-07
828	7.91454E-07
829	7.47077E-07
830	7.05386E-07

The V(λ) values in this table are from the 'CIE "physiologically-relevant" luminous efficiency functions consistent with the Stockman & Sharpe cone fundamentals' listing available at http://www.cvrl.org/, the website of the Colour & Vision Research Laboratory of the Institute of Ophthalmology, which is part of University College London. The values were downloaded as a file entitled linCIE2008v2e_1.csv on 9 January 2013.

3.2 Reporting V(λ)

Measurements made with the luminous efficiency function specified in this Standard shall be identified as being "per ANSI E1.48 V(λ)."