MEMORANDUM FOR: Record 7 September 1998

SUBJECT: International Symposium on the Measurement of Optical Radiation Hazards (MORH)

1. Dr. David H. Sliney and most of the technical staff of the USACHPPM Laser/Optical Radiation Program participated in the subject symposium on 1-3 September, 1998 at the National Institute for Standards and Technology (NIST), Gaithersburg, MD. The MORH was organized jointly by the ICNIRP, the CIE Division 6, NIST and USACHPPM.

2. Dr. Albert Parr, NIST, welcomed the participants and briefly described the organization and work of the NIST.

3. Dr. Jack J. Hsia, President of the CIE welcomed the participants and briefly described the role of the CIE.

4. Dr. David H. Sliney, Director of Division 6, CIE, welcomed the participants and provided an overview of the activities of Division 6 on Photobiology and Photochemistry. He explained that the Division normally met about once each year, and this was its first effort to hold a major international symposium. He briefly outlined the activities of the CIE Division 6 and listed the major TC activities in photodermatology, basic photobiology and photochemistry, ocular effects, lamp safety and health.

5. Dr. Rudiger Matthes, the Scientific Secretary of ICNIRP, welcomed the group on behalf of ICNIRP, and explained the history and role of ICNIRP. He explained that ICNIRP grew out of an International Non-Ionizing Radiation Committee of the International Radiation Protection Association (IRPA). ICNIRP is organized as a main commission with four subcommittees on epidemiology, physics, biology and optics. Its main role is to assess possible adverse health effects based on established scientific knowledge and to produce guidelines on limiting exposure. It also provides technical advice on practical implementation of their guidelines and issues statements on practical problem areas, such as one on fluorescent lighting and malignant melanoma, and another on sunbeds. He explained that ICNIRP has also published joint publications with the World Health Organization, the World Meteorological Organization, the United Nations Environmental Program and the International Labor Organization.

6. Dr. Elizabeth Jacobsen, Food and Drug Administration (FDA), Center for Devices and Radiological Health (CDRH) welcomed the group on behalf of the FDA. She explained that CDRH had a special interest in the area of photobiological hazards and had developed an internal Photosciences Network to cover the different areas in FDA concerned with potential hazards of optical radiation. She explained that under a new Congressional Act, the FDA was recognizing hundreds of voluntary standards such as those of ISO or IEC which could be used by applicants for new drugs or devices.

7. Dr. Thomas Coohill, President of the American Society of Photobiology, gave an opening presentation on action spectrum. He explained that if one examines individual cells, such as bacteria, it is possible to minimize the effect of absorbing and scattering of tissue. He told the story of a study by Gates in the 1920s who had began with the assumption that proteins were

the key molecules damaged to create a bacteriocidal effect, but was able to show that DNA actually appeared to be the target molecule. He explained that even single layers of mammalian cells can have the appearance of an action spectrum varying from DNA, but in fact is not. Another effect, a photoimmunologic effect from urocanic acid, could be isolated from that from DNA. He showed how action spectra could even vary with environmental conditions as illustrated by action spectra measured in the antarctic on different days.

8. Dave Sliney presented a talk on the uncertainties in action spectra produced by the use of different light sources during biological research. He emphasized the effect on the slope of rapidly changing action spectra as a result of monochromator bandwidth. He also described the impact of means of assessment and choice of endpoint, and pre-shielding of the active chromophore. He gave an example of how a true action spectrum would be altered by the experimental methods.

9.   Prof. Frederick Urbach, emeritus Professor of Dermatology, Temple University School of Medicine, spoke on the history erythemal action spectra. He noted studies dating back to 1820 which revealed that sunburn was not Widmark in 1889 first clearly showed that UVR was responsible for erythema by the use of window glass absorbers to shield on UVR. Widmark ended his paper in 1889 with the conclusion that the UV absorption of the atmosphere was responsible for allowing life to exist on the planet. Hauser showed in 1920 the first action spectrum for erythema using a quartz, mercury-lamp monochromator system. Hauser also showed how the degree of redness varied greatly with wavelength and time of assessment. However, in the 1960s, with the use of monochromators with xenon arcs and a more subtle assessment of erythema led to less defined action spectra without the strong dip at about 350 nm. He then showed the action spectrum of Parrish and Gange which extended to about 400 nm. Using the action spectrum for DNA alterations published by Peak and Peak, he showed the sharp change in slope between 335 and 345 nm.

10. Prof. Brian Diffey, Newcastle-upon-Tyne, UK, spoke on the CIE standardized erythemal action spectrum which he developed in 1987 with Dr. Alistair McKinlay. He described the method he had used in more than 2,000 patients in recent decades for phototesting using a single-grating monochromator. He used a 5-nm bandwidth at about 305 nm, but a 30-nm bandwidth at 350-380 nm. He showed an instrument to test redness and explained that UV-C was very effective at very low degrees of redness, but very inefficient for deep redness.

11. Prof. Angelika Anders, Prof. of Biophysics, University of Hanover, spoke on the use of tunable dye lasers for determining action spectra, as for erythema. She emphasized the high spectral purity of lasers with spectral bandwidths less than 1 nm. She noted that at wavelengths below 330 nm there were no useful tunable lasers, and it was therefore necessary to employ non-linear for   24 hours after irradiation for skin types II and III. She noted the small maximum in the UV-A at about 360 nm. She compared her high-resolution action spectrum with IPD which showed a slight shift. She compared her action spectrum with that of Parrish and Gange and the McKinlay-Diffey action spectrum. She also showed the distinction with the DeFabo-Noonan action spectrum for immune suppression in mouse skin.

12.   Prof. Jean-Pierre Cesarini, Rothschild Foundation, Paris,

spoke on action spectra for photosensitization. He explained that there were photo-auto reactions and photo-hetero photosensitive reactions. He also distinguished between Photo-irritant contact dermatitis (PICD) which occurs on a first exposure and photoallergic contact dermatitis (PACD) which requires repeated exposures. He then descried how different mechanisms were involved: Type I which was due to a radical, whereas Type II involved singlet oxygen. Many molecules could be involved, from lipids to amino acids. Besides the photo-auto reactions which produced sunburn-type photodermatoses, there are inherited or acquired porphyrias and constant dermatoses.
He listed groups of photosensitizing molecules and then showed families of action spectra which were either an enhanced sunburn action spectrum or a shifted action spectrum going well into the UV-A. He noted that non-steroidal anti-inflammatory drugs were frequently phototoxic and some might even lead to photoallergies.
He then described photodynamic therapy (PDT) used to treat cancers, but these lead to lengthy photosensitization that can last a month. Also fluoroquinolones can be photosensitizers, and this led him to discuss a recommended process for phototesting of drugs. He summarized by stating that most action spectra were int he UV-A and UV-B.

13. Dr. Frank DeGruijl, Utrecht, the Netherlands, spoke on UV skin cancer action spectra. He began by explaining the hypothesized mechanisms of photocarcinogenesis working through proto-oncogenes and tumor suppression genes. He showed that spectral studies of DNA modifications in cell cultures, showed two peaks, the primary in the 300 nm band and a second in the UV-A. Using studies of the p53 gene mutations in skin cancer, it was possible to obtain action spectra for different changes. Although in-vitro action spectra could be obtained for direct changes in DNA, etc., it was far more difficult to obtain action spectra from mouse studies using different polychromatic light sources. This was done, however, in the development of the SCUP skin cancer action spectrum. Using a special 365-nm lamp, they showed a relative effectiveness of about 0.0001 of the 295-300 nm peak. He compared this with the laser-erythema action spectrum of Anders, et al. and showed very good agreement in the UV-A. He ended by stating that in melanoma, there were clearly more steps in the process of carcinogenesis. He also noted that squamous cell carcinoma appeared to be related to lifelong sun exposure; whereas, basal-cell and melanocytic skin cancers appeared to be related to occasional or childhood over exposures.

14. Dr. Donald Forbes, Argus Research Laboratories, PA, spoke on the development of a CIE recommended standard action spectrum for photocarcinogenesis of non-melanoma skin cancers. He showed photographs of animal phototesting under solar-simulators. He showed the emission spectra of a xenon arc as filtered by two types of glass spectral cut-off filters (e.g., Schott WG320 and WG345 nm. He explained that current animal testing normally took 1-2 years to allow sufficient time for tumors to develop. He explained that the CIE Committee started with the SCUP action spectrum and revised it to have a horizontal line from 340 nm to 400 nm in the UV-A. Despite similarities with the CIE Erythemal action spectrum, the photocarcinogenesis action spectrum had higher values from 305 to 330 nm, but then did not have the slope from 340 to 400 nm. He showed how a slight shift in a cutoff filter for a lamp would cause significant differences. He also noted that if an action spectrum for a more severe form of erythema were used, the relative contribution of UV-A and UV-B would be about the same as the CIE photocarcinogenesis action

spectrum.

15. Dr. Janusz Beer, CDRH/FDA, read the paper of Prof. Edward DeFabo, George Washington University, on photo-immunosuppression by UVR. He explained that UVR produced suppression of contact sensitivity. He and Prof. Noonan proposed that urocanic acid, present in the stratum corneum played a key role and that cis-UCA was the chromophore and its isomerization to trans-UCA lead by some biochemical changes to immune suppression. Kripke and colleagues, however, had argued that DNA was the target molecule, and later, Dr. Kripke proposed a model which attempted to explain the differences and the role of both DNA and UCA. He concluded that UVA may not play as great a role as once thought, but in any case, it appears

16. Dr. Lorraine Kligman, University of Pennsylvania, spoke on photoageing of the skin. She showed a clinical example of a 64 year old woman who looked far older than her actual age. At one time it was thought that UV-B was the major actor in photoageing, but today there was ample evidence that UV-A also played a significant role. She employed the hairless mouse as an animal model for her studies. She showed histological slides of normal and aged skin. Elastosis in the mouse looked just the same as in the human from a histological standpoint. Elastosis differed whether a UV-B or UV-A source were employed. UV-B produced a stiffled effect upon collagen, but UV-A produced dense deposit at the dermal-epidermal junction and the collagen fibers looked more normal. However, the collagen really is changed by UV-A radiation and the collagen is rendered insoluble and undigestible by pepsin. The basement membrane and structure of vessels were severely affected by both UVB and UVB. She explained that UV-A and UV-B played a role and UV-B was actually more severe that UV-B. She described an experiment using spectral with different cutoff filters, WG-320, WG-335, WG-345 and WG-360. She then traced elastin fibrils in photomicrographs to determine the degree of elastosis and this was analyzed by image processing to show that the action spectrum compared favorably with the CIE standardized erythemal action spectrum. She had found that the thresholds for 50% changes as a function of radiant exposure and wavelength.

17. Prof. George ("Bud"), Thomas Jefferson University Medical School, Philadelphia, PA, spoke on the neuroendocrine effects of light. He noted that in a range of animals, it was blue-green light responsible for the circadian rhythm, but the chromophore was unknown. He explained the neural pathway for circadian control in the human involved the SCN, the PCN and the LGN to control the melatonin cycle. He explained that bright light (2500 lux) suppressed plasma melatonin in normal humans. He described continuous monitoring studies of plasma melatonin as a function of wavelength and this peaked at 509 nm (10-nm FWHM). At 450 nm there was no effect, but at 509-nm there was maximal effect; whereas, at longer wavelengths the response became less, and suggestive, but not statistically clear, of the rod function. Later, he was involved in studies at NIH on seasonal affective disorder (SAD) where phototherapy was used. In a study where red (615-685 nm) and green (505-555 nm) light was used, the green was clearly more effective. In another series of studies, they measured plasma melatonin when subjects looked into bright light ganzfeld. Using this technique, found that there was no significant difference between protanopes, deuteranopes, and normal color vision. He suggested that another chromophore might be involved, such as melanorhodopsin which may not even be in the

retinal photoreceptors but appeared to be in the ocular globe.

18. Dr. Joseph Zuclich, Brooks AFB, TX, spoke on UV action spectra in the cornea. He showed the anatomical structure of the cornea, noting that the epithelium was 50-100 æm the stroma about 500 æm and the endothelium was on 5 æm in thickness. The epithelium consisted of three layers and the lifetime of an epithelial cell from basal to squamous was about 7 days. He showed that the basal cells swelled and there was a sloughing off of surface epithelial cells. He showed that reciprocity held from about 10 ns to 10 ks at 350 nm. To examine recovery time, they performed a number of studies where two exposures were separated to determine the combined effect, and showed the recovery time being about two days.

19. Prof. Anthony Cullen, University of Waterloo, Waterloo, Ontario, spoke on studies of UV-induced cataract. He explained that a variety of animal models had been employed, but he concentrated on his rabbit studies. They had obtained data at 295, 300, 305, 310, 315 and 320 nm. The lens epithelium was seriously affected. As more lens fibers are laid down, then the area of damage migrates. He noted that studies of Andley had shown that the action spectrum and thresholds for UV damage of cultured, exposed lenticular epithelial cells was very similar to corneal epithelial cells. He therefore suggested using the corneal epithelial photokeratitis action spectrum adjusted for spectral transmittance of the ocular media. He then switched to studies of infrared cataract. They could not achieve experimental cataract without exposing the iris. They found reversible cataracts at 2250 J/cm2 in 485 s exposures and they also produces a sticking of the iris to the lens. He noted that the melanin in the iris absorbed very little energy at wavelengths greater than 900 nm. He also noted the effect of temporal exposure--the Coroneo Effect. He concluded that one could develop empirical action spectra based upon corneal epithelial damage data.

20. Dr. Tsutomu Okuno, Japanese National Institute of Industrial Health, spoke on his mathematical model of temperature elevation of the lens as a function of variation of wavelength in the infrared. Using a finite-difference method, he computed temperature rises as a function of wavelength. The lens temperature rose steadily for the first minute but had reached a maximal value in less than 2 minutes. The peak temperature occurred at the iris for visible and IR-A, but the peak absorption was in the cornea for IR-B. He calculated a temperature elevation ranging from about 0.002 to 0.001 degrees per mW/cm2. This means that the temperature rise from industrial operations alleged to produce cataract of 100-150 mW/cm2 would produce a

21. Dr. Kazuyuki Sasaki, Professor of Ophthalmology, Kanazawa Medical University, Japan, spoke on data from epidemiological studies of environmental UV exposure of the human eye. He described cortical, nuclear and subcapsular cataract. The majority of cataracts at age 60 is cortical, but in later years, it appears as a mixed type. He and his group have been involved or performed joint epidemiological studies in Japan, in Singapore, in Reykjavik and Melbourne. Their data collection system is a scheimpflug, slit image and retroillumination image camera system. He showed the variation in lens transparency by age group and location (Reykjavik, Noto, Amanmi and Singapore. A strong latitudinal variation was shown. He showed how the grade

of opacification varied with age and geographical location. The ageing change was much faster in the Singapore group than in Noto and Reykjavik. The onset of grade II and grade III was clearly delayed with increase in latitude. He then spoke about ocular protection and noted the Coroneo Effect of oblique temporal exposure. His mannequin studies showed that some sunglasses increased the exposure over wearing no sunglasses due to reflections from the inside sunglass lens surface. Brimmed hats were sometimes better.

22. Bruce Stuck, the Director of the US Army Research Detachment, Brooks AFB, TX, spoke on the blue light hazard. He summarized different retinal injury mechanisms: the short-duration damage mechanisms of thermal, thermomechanical, and optical breakdown and the photochemical mechanism (photoretinitis). He quoted the conclusion of Verhoeff and Bell (1916) that eclipse retinitis was thermal and there was no effect of UVR on the retina. He then noted that many studies have since shown blue-light damage of the retina: Ham, et al., Sperling et al., Lawwill et al., Noell et al, Marshall et al., Zuclich et al. and Zwick et al. The effect was dominant between 400-500 nm and there was some effect out to 550 nm and the appearance was delayed by 24-48 hours. He summarized the experimental data of Ham et al., for thresholds at 1, 16, 100, and 1000 s for a 500 æm spot size. He showed the calculations of temperature rise by the threshold exposures of Dr. Ham as calculated by Alex Clarke. These showed that all photochemical effects occurred at small temperature elevations of the order of 1 degree Celsius. He described briefly the action spectra used by ACGIH and ICNIRP which were derived from these studies.

23. David J. Lund of the US Army Research Detachment, Brooks AFB, TX, spoke on retinal thermal injury. He noted that the RPE was the principal absorbing layer for retinal thermal damage. Using a primate eye and exposing the retina to tunable-wavelength laser radiation, he reported one-hour thresholds for a minimal visible lesion of the retina. For a minimum retinal image size, he found that the threshold varied from about 1 mJ at 479 nm to 12 mJ at 1064 nm for 0.1 second exposures and this fit the predicted RPE absorption as a function of wavelength. He noted however that for 10-ns exposures there were depressions at three wavelengths, which suggested minima at fifth harmonics.

24. In the Panel Discussion on Action Spectrum chaired by Dr. Dianne Godar, CDRH/FDA, Jean-Pierre Cesarini asked if the animal model for photocarcinogenesis where the rate of exposure would be varied. Don Forbes explained that there was indeed an effect they had once called a ballistic effect where once a tumor developed, many others would follow. This showed an impact of immune suppression effects. With regard to a question on age-related macular degeneration (AMD) and blue light, Prof. Mainster discussed that there had been some studies which found a correlation between the most severe form of macular degeneration and sunlight exposure and some weaker evidence suggesting that blue light might be a causative factor. Dr. Edward Nardell, a public health physician from Boston described his CIE TC effort to provide an updated action spectrum for UV germicidal effectiveness and he noted that the most effective source of UV-C, the 254-nm mercury low-pressure quartz lamp was not much of a risk to humans, since the stratum corneum strongly attenuates that wavelength as reflected in draft CIE action spectrum for photocarcinogenesis. Prof. Mainster suggested that more information in this area needed to be provided for practicing

physicians, and he also suggested the need for an action spectrum for chronic retinal exposure.

25. David Sliney presented an overview of ACGIH TLVs for optical radiation.

26. David Sliney presented an overview of ICNIRP guidelines for limiting human exposure to optical radiation.

27. Jean-Pierre Cesarini presented an overview of CIE efforts to standardize action spectra. He pointed out that in 1986, the CIE, the IEC and the ISO signed a memorandum of agreement for CIE to be the fundamental organization for standards in light, light measurement, radiometry and vision. In 1924 the CIE issued the first visual response curve and colorimetry curves. These curves, since modified, are still used over 70 years later, and are used in medical applications such as skin color as in the CIE L*a*b* System. In 1985-1987 there were several meetings in Europe to standardize a new CIE action spectrum for erythema, and this is now being voted upon as a CIE standard along with the Standard Erythemal Dose (SED) Unit. CIE Publication 90 provided a Sunscreen Testing (UV.B) standardized method that was adopted by the FDA and other groups. He then mentioned the report of CIE TC 6-26 on the division of UVA and UVB at 315 nm. He explained that CIE TC 6-27 had prepared a reference action spectrum for erythema, and there were several TCs developing other action spectra. TC 6-32 had developed the action spectrum for photocarcinogenesis, TC 6-34 was developing a standard protocol for photocarcinogenesis testing. Finally, a CIE TC was developing

28. Dr. Robert Levin, Osram-Sylvania, Danvers, MA, presented an overview of the IESNA RP27 standards on the photobiological safety of lamps and lighting systems. He opened with a statement from Sliney and Wolbarsht, Safety with Lasers and Other Optical Sources (1980) which stated that the lamps were generally not a practical hazard. He reviewed the history of UVR guidelines and the ACGIH TLVs on UV and later, the visible and infrared. He explained that the IESNA Committee on Photobiology had taken over an ANSI Z311 Committee responsibility in 1986 to produce a safety standard, finally approved in 1996 and published in 1997. He described the criteria for labeling into risk groups. General Light Sources (GLS) were treated for hazard evaluation at an illuminance of 500 lx. This illuminance was not intended to represent the actual illuminance in the workplace or home, but was a reference benchmark value for measurement of potential hazards, e.g., the UVR. He defined the risk categories: Exempt, Risk Group 1, Risk Group 2, and Risk Group 3. Only germicidal lamps and xenon-arc lamps might fall into Risk Group 3.

29. Robert Landry, Center for Devices and Radiological Health, spoke on the CIE activities in lamp safety standards. He listed a number of past publications of the CIE relating to lamp safety. He then explained that CIE TC 6-38 examined the need for a photobiological safety standard and recommended development of a standard by the CIE. It listed the photobiological hazards and reviewed worldwide standards activities. It pointed out why exposure limits for a lamp are so much more complicated than lasers. Spectral quantities and radiance must be measured for a lamp source. He then noted the activities of the CIE TC 6-47 on lamp safety committee. CIE TC 6-47 had prepared a draft standard modeled after the IESNA/ANSI RP27 series but employing the guidelines of the ICNIRP. However, it would not have

manufacturer requirements, as that would be the work of the IEC.

30. There was a discussion of the lamp safety standards. Dr. Robert Vinger, Boston, asked how as a surgeon, how he would know that a very bright operating room light. This led to an extensive discussion on whether one could obtain adequate information from lamp labeling or from the manufacturer.

31. Peter Drop, Philips, Einhoven, NL, spoke on the activities of IEC TC 34 on lamps and luminaires. SC 34A on lamps and SC34D on luminaires would have to deal with potential photobiological hazards. To date, this IEC committee had not employed the approach recommended by IESNA/ANSI or CIE TC 6-38, but had applied the ACGIH UVR TLV. He described the permissible exposure time (PET) and also the Ratio EEFF of the effective UV irradiance and the illuminance in lx. There was another unit called PET* which was actually a dose that corresponded to 4 hours exposure. Three standards resulted from this approach: IEC 60598-1, Luminaires safety; IEC 60357: Tungsten-halogen lamps--safety and performance; and IEC 60432-2: GLS replacement TH lamps--safety. For lamps in Europe which do not have an FDA regulation requiring protective enclosures, these standards are important. There is now an IEC standard pictogram symbol which suggests a horizontal cover filter for a lamp in a luminaire. This was a requirement for lamps emitting a specific UV power of 0.35 mW/klm, based upon a very conservative application of the ACGIH TLV. With regards to metal halide lamps, there was a standard IEC 61167 on Metal Halide Lamps--safety and performance, and there was a draft standard IEC 62035 on HID lamps, where there was a maximum allowed specific effective UV power and information must be provided by the manufacturer. There were also pictograms for germicidal lamps, e.g., in IEC 61549, Amendment 2, 1998.

32. Sharon Miller, CDRH/FDA, spoke on their activities in lamp safety standards. She pointed out that under the Radiation Control for Health and Safety Act of 1968, the CDRH had been empowered to regulate the radiation emission of electronic products and this had now incorporated in to the FDAM Act of 1997. the CDRH had promulgated two federal regulations: 21CFR 1040.20 on Sunlamp products and 21CFR1040.30 on HID lamps. She pointed out that they had measured and evaluated sunlamps, quartz halogen lamps, fluorescent lamps and ophthalmic instruments. She described the most recent evaluations of ophthalmic endoilluminators. They had employed the ACGIH aphakic hazard function to evaluate the eight endoilluminators. She noted that the risk was far greater from a unit which employed a xenon-arc. All of their units exceeded 0.05 mW/cm2 at 5 mm from the probe tip recommended in a draft ISO TC172 standard. She noted that the ACGIH limit was exceeded in 0.5 to several minutes. She showed that short-wavelength filters could greatly reduce the risk and lengthen the safe time.

33. Prof. John Mellerio, University of Westminster, London, spoke on the design of effective solar protection for the eye. He began by noting that risk can be reduced by avoidance, reduce exposure duration and reduce intensity. A number of radiation protection working groups had examined eye protective devices. Normally any user has to apply a guideline to define the source radiation characteristics and determines the exposure duration and determines the minimum protection. In the special case for a constant source, such as the sun, it is possible to obtain some general guidance, except that sunlight does vary hourly and

ground reflectance has a major impact. A number of worst case analyses, as might occur on a Florida beach. He showed the action spectra for retinal injury from Noell, Ham, van Norren and compared this with the absorption spectrum of the RPE. There are two types of retinal hazard and labelled as Type 1 (the blue-light hazard) and Type 2 (the Noell effect). He showed the recommendations of the ANSI Z87.3 - 1986 standard and BS 2724 - 1987 and both had somewhat similar requirements for sunglasses. Because of concerns with regard to traffic signal recognition, several standards, such as EN 1836 specified a Q factor, which he showed was rather flawed, and then explained that other standards such as the ANSI and also the Australian (AS 1067) standard treated color differently. He looked for an international standard to resolve some of the traffic signal recognition rules.

34. Dr. Ernst Sutter, Physikalisch-Technische Bundesanstalt in Braunschweig, Germany spoke on IEC TC76 activities in broad-band exposure limits. He opened by stating that there had been no real activities in ISO on welding filter standards developments, but there was new data to suggest that the near-UV requirements were too restrictive, but then he noted that many welders used lower shades that intended in the design. With regard to IEC TC76, he explained that an IEC report on this (IEC 60825-9-1998) had been approved in July 1998. He argued that there should be no difference between laser and incoherent exposure limits for the same radiation source. He presented limits for laser radiation and then described different incoherent limits. He said that there was no safety factor in the UV TLV. With regard to retinal limits, he compared the incoherent limits for blue light and retinal thermal noting that the crossover point was about 35 seconds. He made a comparison of incoherent limits for minimal images with laser limits and suggested that the incoherent limits could even be more conservative for blue lights.

35. Prof. Myron L. Wolbarsht, Duke University, NC, spoke on the action spectrum for phototherapy of newborn jaundice (hyperbilirubinemia). He noted that bilirubin is a metabolite of hemoglobin and remains in the blood stream. The peak of the bilirubin absorption spectrum is 440 nm, but when combined with albumin, the absorption shifts to 480 nm. At one time their was a special lamp, F20T12/BB which appeared to simulate the absorption spectrum of bilirubin. However, there appeared to be some anecdotal evidence that white light bulbs were more effective. Pratesi (1985) showed that there was an isomer absorbing with a maximum near 514 nm, but Prof. Wolbarsht was skeptical that this was really valid. He then explained that there was not a good measure of the effectiveness of phototherapy. The clinical gold standard was a measure of blood samples, but this was impractical. This led to a research attempt in his laboratory some years ago to measure the change in skin reflectance in the 400 and 550 nm. They were able to predict the level of serum bilirubin from their skin spectral reflectance instrument. They found that the Westinghouse F20T-12 lamp had a rather rapid decay in output, where the output dropped nearly 50% in 1,000 hours. He suggested a disposable lamp which decayed in output blue light. He was not enthusiastic for blue light blankets now used in NICUs.

36. John DeLuisi, National Oceanographic and Atmospheric Administration, Surface Radiation Research Branch, Boulder, CO, spoke on their UV network in the USA. He explained that they had

a NIST standard of spectral irradiance and a Field U1000 (SUNY-Albany) high resolution spectroradiometer which was used in the calibration of multi-band meters, portable spectroradiometers and broad-band meters. He showed photographs of their Solar Light and Yankee broad-band meters under test at their Table Mountain, CO, which were annually calibrated and recorded when returned for calibration or repair. He described the ISIS Network of UV monitoring stations spread over the USA. He also discussed the older Robinson-Berger network data which showed a very good correlation in 1984-1986 between the Solar Light R-B meters and TOMS ozone monitoring earth satellite data. He showed that there was a marked divergence between the TOMS prediction and the R-B meter in Minneapolis in the winter time. This was due to the impact of snow which kept the TOMS satellite from distinguishing cloud cover.

37. Dr. Colin Roy, Australian Radiation Laboratory, gave a summary talk on action spectra. He showed a log-linear plot of action spectra for both skin and eye, showing some of the action spectra that have been published. He compared permissible exposure durations for several sources, which showed times of 1 - 5 minutes for arc welding to 15 minutes and longer for solar radiation. This posed a problem for the employer of outdoor workers. He showed the strong impact of wavelength sensitivity of the CIE standard action spectrum for erythema. To illustrate this, he modified the CIE spectral weighting by shifting all values 2 nm to shorter wavelengths. By doing so, the integrated daily solar erythemal exposure dropped by nearly a factor of two. He noted that the "Radiation Amplification Factor" for a depletion of ozone due to shifts in the spectral irradiance to shorter wavelengths. He showed how different countries reported global UVR as "very high," "high" or "moderate" at different ranges of UV indices. He argued for a combined carcinogenesis, erythema index for public health and the guidance for protection should be limited to a maximum of three ranges of UVI.

38. Richard Vincent, St Vincent's Hospital, New York, NY, spoke on air disinfection by UVR. He explained hat there were CIE TCs related to a standardization of a germicidal action spectrum, one on UV air disinfection and one on UV water disinfection. He showed how tuberculosis case rates had increased again since 1978 from just over 1000 cases in NYC to 5,700 in 1992. The WHO reported that 1/3 of the world's population was infected by TB and TB was the number one killer of young women in the world in 1994. He explained that upper air UV irradiation would greatly improve the effectiveness of ventilation. He described a controlled field trial of efficacy in New York, Boston, Birmingham and New Orleans. They used an IL1400/SEL240A meter to monitor the effectiveness of their installations. They had a real problem designing good fixtures, since the 12-14 foot ceilings characteristic of the 1940s and 1950s are no longer typical and they had little upper air volume to irradiate.
39. Charles Campbell, Humphrey Instruments, California, described the ISO TC172 Subcommittee SC7 on ophthalmic optics and Instruments, Working Group WG6 has been developing standards on light hazards. They followed a general philosophy to consider only visible radiation where elimination of non-useful infrared and ultraviolet radiation. They concluded that the only conceivable photobiological hazard was the "blue-light hazard." They applied the ACGIH B(þ) and A(þ) functions and require the manufacturer to inform the user of the blue-light and aphakic radiance of the instrument under maximum output. He explained that a patient's normal avoidance to bright sources is usually

blocked, the pupil is often dilated, and a natural pupil may or may be the system stop, the exposure time is quite variable and the retinal recovery to photochemical insult may be compromised due to the disease. The geometry underlying the specified radiance limits considered the special optics used in different instruments. For example, the slit lamp biomicroscope is frequently used in two different modes: for viewing the anterior segment or the retina. To view the retina, direct funds viewing is possible with the introduction of a gonioscopic contact lens or indirectly with an ophthalmic viewing lens, such that the effective aperture was quite different. This had to be taken into account in the generation of these standards. Developing the standard required a complicated approach because of the lack of measuring instruments and other instrument design problems, they set about deriving a UV filtering requirement to limit the aphakic retinal exposure. This was the aphakic radiance limit of 100 J/(cm2ùsr) reduced to 1.76 J/(cm2ùsr) from taking into account the change in pupil size from 3 mm to 8 mm. They then assumed a black-body source spectrum and demanded that the UV component not contribute more than 1/8 the total blue-light hazard.

40. Ray Lambe, National Physical Laboratory (NPL), Teddington, England, spoke on the radiometric measurements to evaluate a source under the draft standard, ISO 15004:1997(E). He quoted the UV requirement of 0.05 mWùcm2 and 100 mW/cm2 at wavelengths greater than 700 nm and less than that emitted in the visible. He stated that there were several approaches to measure the ophthalmic instrument. Although a broad-band radiometer would be desirable, it was not available, and since spectral data was needed anyway, one should really apply spectroradiometry. He compared the NPL standard for spectral radiance (a ribbon-filament lamp) to a Marcher Enterprises fundus camera submitted to him for measurement prior to submission to the US FDA for device clearance. They measured the relative spectral power distribution using a continuous scanning spectroradiometer. They prepared a 26 page final report of their measurements with uncertainties. They had difficulty comparing the criteria for normal use, e.g., when the source was switched on. He suggested the need for a change in the standard such that seemingly innocuous sources such as an infrared focusing source used with the lamp.

41. Dr. Charles Campbell led a panel on the impact of standards upon product safety. Robert James, FDA/CDRH, felt that the stability of standards was important and that standards would at least afford a modicum of safety. Robert Levin noted that there were frequently minor, highly detailed changes in standards which made them slightly incomparable and very difficult for an international corporation. Peter Drop emphasized that standards frequently had been used to constrain trade and he noted that a NIST flyer explained to US manufacturers that they had to put a CE mark on any electrical or electronic product imported into Europe that it complied with all European standards. Peter Drop argued that it was possible to be non-compliant with a European standard, but there had to be a "declaration of conformance," etc. Jean-Pierre Cesarini gave an example of how effective the IEC standard by WG 61 was used to limit dangerous exposure from sunbeds.

42. Serge Forestier, L'Oreal Recherche, France, spoke on Sunscreen testing. He noted that FDA argued that greater UVA

protection was needed in sunscreens in 1994 (Federal Register). He described several methods proposed for describing the UVA protection. Four in vivo (human subject) test methods had been proposed. In I987 Lowe proposed a phototoxic protection facto, and in 1991 Kaidbey proposed IPD, J and J proposed in 1994 a UVA protection factor, and Minimal persistent Pigment Darkening was proposed in 1996 was proposed by the JCIA. Other groups as in Australia had proposed in-vitro test techniques. The Australian method required that an 8 æm film must not transmit less than 8% between 320 and 400 nm. Brian Diffey had proposed in 1994 for the CTFA a method of a critical wavelength where the transmittance reduced to 0.9 and this critical wavelength if less than 370 nm allowed only UV-B/UVA, but if it were to be greater than 370 nm, it would be called "broad-spectrum." His laboratory embarked on an effort to evaluate the different approaches. They examined five different products with different labelled SPs but similar critical wavelengths less than 370 which ranged from 352 to 358 nm. There were a large deviation of the UVA protection for different SPFs. For products with a critical wavelength greater than 370 nm (i.e., from 376 to 379 nm), they found still a great difference, but in general the UVA PF was less than the SPF. In an assessment of four selected European (and three American) Broad Spectrum sunscreen products he found significant problems. He showed how one could formulate two products with the same SPF, with a critical wavelength greater than 370 nm but two quite different in vivo SPFs. He also quickly described the in vivo UVA protection factors (PPD). The in vivo technique clearly shows ability to properly take into account substantivity and other factors. He concluded that the industry wanted an in vivo method but it had to be proofed against well accepted in vivo methods.

43. Natasha van Tonder, South African National Metrology Laboratory and chair of CIE TC 6-36 on the UV protection of shading materials and structures, spoke on studies of UV protective materials of umbrellas and similar structures. They measured umbrella materials in a laboratory with a spectroradiometer and broad-band measurements were made of scattered radiation coming in under the umbrella from different directions over different earth surfaces. She showed that significant UVR still could reach the person under the umbrella.

44. Pierre Cesarini, Securite Solaire, Paris, France, spoke on his program which translated the data from La Meteo Solaire to the UV Index which was publicized on the TV media, a web page, in newspapers and posted at beaches. They also produced childrens' books which explained the UVI and why one could receive a sunburn even on a cloudy day. They also had a board game where a child could win by not getting an overexposure of UVR. They also had a science experimental kit for measuring UVR with a color-change paper, measure shadows and test protection. Prof. Jean-Pierre Cesarini noted that they had progressed and polls of the public showed a great increase in public awareness of UV hazards.

45. In a panel discussion on Problems in Standards chaired by Prof. Jan Stolwijk of Yale University, New Haven, CT, there were some spirited discussions on what future standards were needed. Dr. Sliney suggested that two or three research topics were revealed in the earlier presentations, such as the need for reproducing retinal injury thresholds at 442 nm for 0.1 and 1.0 s exposures as this led to the unexpected behavior of the R-lambda function in the 400-500 nm band. He also noted the debate on whether there was a photochemical mechanism for cataract, and

this was echoed by Prof. Wolbarsht. Dr. Sutter argued that limits of exposure for lasers and incoherent sources should be the same for the same wavelength, disagreeing with the position taken by ICNIRP and other health scientists, and he chastised the US for not always following International standards.

46. Yoshi Ohno, NIST Optical Technology Division and Secretary of CIE Division 2, presented a talk on what could be learned from photometry. He explained that CIE Division 6 considered the physical measurement of light and radiation. He cited CIE Publications 63, 64 69 85 and 105 on spectroradiometry and characterizing meters. He explained that CIE Division 2 had just established a new TC 2-47 on the Characterization and Calibration Methods of UV Radiometers, chaired by Dr. Xu of Singapore. He then explained how spectral mismatch problems are dealt with in photometry. He showed how a spectral mismatch of a photometer had different relative errors depending upon the spectral distribution of the source measured. These could be serious for some LEDs. There were methods to calculate the spectral mismatch correction factor for different light sources, such as CIE Illuminant A. The spectral mismatch factor f1'is described in CIE Publication 69. He used a function F* (þ) to indicate the monochromatic error at each wavelength. In his experience in evaluating white light sources, the spectral mismatch term is generally within the value of f1'. He said that state of the art photometers had f1' of 1.2%. By applying this approach to UV meters against the CIE Erythema action spectrum, he obtained f1' of 38 and 78 % and very large correction factors. He suggested two methods for UV meter calibration; one related to the f1'approach and another was to calibrate against a reference source, e.g., a solar simulator.

47. Terry Lyon, USACHPPM, spoke on measurements of radiance. He first described the meaning of radiance as referenced against an isotropic source. He noted that it was important not to be confused with luminous or radiant intensity. He also noted that Efficacy of Radiation was also quite useful to convert measured luminance to the radiance of various sources in a given spectral region, e.g., 400-1400 nm. He then pointed out the value of Lambertian reflectors and how brightness does not vary with distance or viewing angle despite the fact that the irradiance drops as the inverse square of the distance (at some distance) and varies as the cosine of the viewing angle with a normal to the illuminated surface. He explained that radiance is a radiometric invariant and lenses and mirrors cannot increase the radiance, but could degrade the projected radiance. He cited four general methods to measure radiance: direct measurement with a spot radiance meter, source masking with irradiance measurement, photographic measurements and witness boards in the image plane of a lens. The carbon paper sensor had two discreet threshold changes which could be calibrated.

48. On Thursday morning, Wesley Marshall, USACHPPM, presented an initial overview of the use and limitations of broad-band instruments. He described three types of measurement devices: a thermal detector, a quantum detector, or chemical actinometry. Filters may be used to tailor the spectral response of a detector to closely match an action spectrum. Quantum detectors were most frequently used with a tailoring filter. A water filter could be used in front of a thermal radiometer to simulate the energy arriving at the eye's retina. Cosine correction could be achieved with a detector by adding a diffuser. Field of view had to be adequate to collect all of the source energy, as with a

very large thermal source. Alignment of the detector with the source was important and should be relevant to the biological exposure, e.g., where the worker's eye would be located. By measuring both radiometric and photometric quantities, it is possible to obtain an approximate radiant efficacy of the source and then use more portable luminance meters to assess the approximate radiance of the source. To measure source size it was frequently effective to apply photographic techniques. For UV assessment, it was possible to improve the accuracy of a measurement by using a short-wavelength blocking filter and subtracting the stray light; and one can provide source-specific calibration. Measuring pulsed sources pose added problems. Silicon detectors can saturate and it is necessary to add neutral filters to be certain. Pyroelectric detector-based instruments often employ a chopper which may create a serious error. In the end, the measurements must serve a purpose, and are generally aimed to determining the type of protective measures. He argued that broadband instruments provide quick and easy results and he emphasized that accuracy is not essential if a lack of hazard can be established. Once a hazard has been established, then more comprehensive evaluations may be performed.

49. Bob Saunders of the Optical Temperature and Source Group of NIST spoke on the spectroradiometric basis for calibration. He stated that the primary irradiance standards used by NIST for optical spectroradiometry are the deuterium lamp in the short UV from 200 to 400 nm and the 1 kW quartz halogen tungsten lamp. The chain in achieving the irradiance scale began with a temperature scale (HACR) to determine the radiance from a blackbody which then could be used as an irradiance source to calibrate working standards used in the field. He explained that they employed a Facility for Automated Spectroradiometric CALibrations (FASCAL) for spectral irradiance measurements. He displayed an uncertainty table for type a and type b measurements. The relative expanded uncertainty (REU) with respect to SI units was about 1.82 % at 250 nm and was slightly less for longer wavelengths for the tungsten halogen reference standard lamps. With regard to the deuterium source, the REUs were 3-4 % throughout the UV region. He hoped to improve these REU values for the deuterium source based upon intercomparisons with the NIST Synchrotron. He explained that they participated in international CCPR intercomparisons. He showed a graph of the percent differences from 250 nm to 2500 nm in their last international comparison of spectral irradiance. For the most part the differences were only a few percent at wavelengths less than 1000 nm. He stated that the most important aspect in any experiment or a calibration is to employ the measurement equation to determine the combined uncertainties. He listed the factors which would influence a spectroradiometric measurement, such as the responsivity of the detector, the slit width of the monochromator, stray light, etc. He gave a comparison of the spectral irradiance distributions of a number of sources that they measured, such as tungsten-halogen source, the SURF, an arc and a deuterium lamp source. He then switched to describing measurement problems, such as scatted radiation and the error resulting from scattered radiation from other sources. He described the "point-spread function" which indicated the relative instrument reading as a source moved across the field-of-view (FOV) of the spectroradiometer. Real-world optics generally provided scatter of the order of at least 10-7. He then described how stray light would produce a significant error when measuring a rapidly changing spectrum such as the sun. 10-9 was considered very good. He concluded with several elements

important in achieving a good measurement. These were the stability, linearity, polarization,uniformity and spectral purity.

50. Dan Berger, President of the Solar Light Company, Philadelphia, PA, described the principal of the Robertson-Berger instrument. He gave an historical note that Terry Roach of CBS Laboratories visited his physical laboratory at the Temple University Skin and Cancer Hospital back in the 1970s to calibrate their sophisticated NIOSH UV meter, but they stopped that project because of the high cost and did not produce a final commercial instrument. This led him to modify the R-B solar radiation meter to work at lower wavelengths. He explained the elements of the R-B magnesium-tungstate meter which required a UG11 glass filter to block visible light, the MgWO4 phosphor, a 4010 filter to transmit the fluorescence to a phototube such as the 1P39. The instrument responded well to sunburning wavelengths around 300 nm, but also had a slight response in the 480-590 nm band. The Solar Light Company Model 501 UV-Biometer was based upon an initial design for a sunburning meter developed in Australia by Dr. Donald Robertson at the University of Queensland during the 1950s. In the early 1960s, Harold Blum, the NIH researcher who had pioneered mice studies met Don Robertson and suggested that the Temple University team employ this method to monitor solar UV in Philadelphia and in Galway, Ireland. From those two monitors, the UV Monitoring Network grew to many more stations around the world. He then showed examples of UV safety meters, such as the Solar Light Company Model PMA2100 portable safety meter. These were similar to the solar meters, but employed a UG5 filter in place of the UG11 filter to expand sensitivity to the UV-C. He showed the spectral response of their PMA2120 MgWO4 instrument which when calibrated to provide measurements of different welding arcs could be reasonably good--within about 15% for three types of welding arcs, but when calibrated for the arcs, was over-responsive by as much as a factor of ten in the 305-330 nm band with the result that it would be inappropriate to use for sunlight. When calibrated for sunlight, it could be very reasonable as well.

51. Alex Ryer, the Engineering Director of International Light, Inc., spoke on the use of interference filter radiometers for hazard evaluation. They used a cosine diffuser, an interference filter to provide the bandpass, and a solar-blind photodiode to make their detector. They had a compact readout unit. He stated that the advantage of his type of instrument (as well as the Solar Light instrument) was that the units were portable and reasonably inexpensive. He stated that there were more elements to accuracy than the concern over spectral mismatch. He argued that "accuracy" had elements of repeatability, linearity over a wide dynamic range, and spatial accuracy as well as the spectral accuracy -- or inaccuracy. He showed how the cosine response should be plotted in polar coordinates. He argued that a cosine response was important for meters assessing skin exposure to UVR. He showed the match of the IL 1730 was fairly good from 270 nm to 330 nm, but overstated the exposure in the 230 - 270 nm. He explained they one could calibrate the instrument for any special source.

52. Dr. Neelam Gupta, Sensors and Electron Devices Directorate, US Army Research Laboratory, Adelphi, MD spoke on acousto-optical wavelength tunable filters used in a small, portable spectrometer. She gave a list of problems with conventional spectrometers. Her objective was to develop such small

spectrometers was for field detection of chemical and biological agents. She stated that the AOS had no moving parts, was reliable, reproducible operation. The entire principle was based upon an acousto-optical tunable filter, which was a birefringent crystal which was turned into a diffraction grating by applying an RF signal. She described two possible configurations: collinear or non-collinear. She listed a range of materials depending upon the wavelength region. The only material which could be used in the UV region was crystal quartz, where the figure of merit was only 1. There were others with far greater figures of merit but they were less developed and did not extend into the UV region. She showed a prototype UV to visible collinear AOTF Spectrometer which weighed about four pounds (2 kg), employing a 15-cm quartz crystal and had a 0.05 - 0.2 nm resolution for a spectral range of 255 - 430 nm with a position error of 0.2 nm a maximum number of points of 4790, a spectral scan time of 5 ms. The unit had to have a high-voltage power supply for the photomultiplier tube (PMT) and the readout was a computer. She showed a high-resolution spectrum of sunlight in the visible, but this was on a linear scale. She also showed photographs of other units which achieved spectra in the infrared and a hand-held Raman/fluorescence spectrophotometer. The dynamic range was 200,000. She claimed that the device had a small dynamic range. The initial design came from the Russian Academy of Sciences. She speculated that the cost in production could be $ 5,000 - 10,000. In a question posed by Ziggy Drozdowicz, she did agree that the source had to be well collimated.

53. Kohtaro Kohmoto, Toshiba Lighting, Yokahama, Japan, and chair of CIE TC 6-14 on the Blue Light Hazard, spoke on a filter detector for studying the blue-light hazard. He briefly explained the blue-light hazard and described the blue-light hazard function published by ACGIH. He stated that as the crystalline lens yellows with age and the attenuation edge shifts to longer wavelengths. He showed the spectral transmittance of intraocular lenses (IOLs) varied in UV-A attenuation (after Lindstrom). He then showed the results of blue light measurements or calculations of a wide variety of sources, such as welding arcs, lamps and the sun. He also calculated how the blue-light hazard would vary with age because of the change in lens transmittance. He calculated that a two year old would have 77% of the aphakic hazard and a very old person about 11%. [Apparently he used some erroneous lens transmittance functions, e.g., from Lerman, since these do not fit with ICNIRP calculations]. He also evaluated ISO 4850 welding filter standards and suggested that protective filters should have more blue-light protection.

54. Dr. Harald Siekman, Berufsgenossenschaftliches Institut fuer Arbeitssicherheit, St. Augustin, Germany, spoke on his experience in performing workplace measurements. He gave a number of problems encountered in field measurements. He showed problems with the lower detection limit, the upper detection limit, in visible sources, varying radiation intensity, a moving worker or moving source, adverse measurement conditions, etc. He therefore explained that one had to have a refined measurement strategy with two instruments. He gave an example of the problem of an uncertain exposure duration, as with a medical assistant who worked with UV and IR lamps. The uncertainty in exposure duration dwarfed any uncertainty in the irradiance measurement. He noted how one could discover a problem, as in a hospital nursery when measuring UVR. He stated that it was important to

specify the measurement objectives; whether the objective was to supervise a worker's exposure, to investigate an accident or a disease causality, to determine the emission of a source, or measure a spectrum or attenuation of a screen. To minimize needless measurement and to optimize the measurement, one must first carefully examine the work procedure. He gave examples of a glassblower who was exposed upon average to about 50 W/m2 (TLV = 100 W/m2), but depending upon task was exposed to a range of irradiances. To select the appropriate instrument, one must analyze the work procedure, determine the uncertainty in the exposure duration, and the type of hazard. He argued that wavelength borders, e.g., in the IR, should be given, that averaging times be specified, that apertures, FOVs and suitable weighting functions.

55. Dr. Andreus Krins, Department of Dermatology, Technical University of Dresden, spoke on polysulfone film personal dosimeters. He thought that with the proper application of polysulfone film (psf) dosimeters, one could achieve reliable exposure dose relationships when calibrated against standards. He explained that the psf spectral absorption in the UV changed in the UV after UV exposure. They used a 20 æm film thickness (rather than 40 æm as used by other groups) and the calibration changed with thickness. When used as film badges, they must be properly applied and worn. They calibrated against a 311 nm monochromator source, and he showed how the spectral response shifted to lower wavelengths for lower doses. He derived an average efficiency function plotted by wavelength to show that the spectral sensitivity compared to the CIE Erythemal action spectrum was shifted approximately 15 nm toward longer wavelengths. Calibrating the psf dosimeters against the Solar Light 501 meter mounted on a roof, they could only apply the calibration over a limited range of sunlight exposure. They were continuing their studies of multispectral effects upon the material, since despite some problems, it was inexpensive and easy to use.

56. James K. Franks, USACHPPM, Aberdeen Proving Ground, MD, spoke on problems of field measurements in the outdoor environment. He explained that changes in ambient sunlight posed special problems, as well as atmospheric attenuation and scattering, temperature and humidity changes, and electromagnetic field (EMF) environment. He explained that the choice of instruments depended on the source and noted that impulse noise affected pyroelectric detectors, and insects and other creatures can affect the ease of performing field measurements. To exclude solar background, one can always take measurements at night. He noted that when using thermal detectors, the movement of a person can change the background. Photocathode response varies with ambient temperature as shown by a study of James and Landry in the 1970s. He gave an example of measuring the muzzle flash from a canon which also emitted an EMF pulse, and portable radios can also provide a spurious readings due to EMF. He showed a photograph of a Photo Research telephotoradiometer 1980P and how it could be used. He spoke of the portability of equipment. He showed how measurements could be made around explosions using witness boards.

57. Patrick von Nandelstadh, Finnish Institute for Occupational Safety and Health, spoke on the measurement of UVR and blue light from welding arcs. He explained the meanings of MIG (GMAW) and TIG (GTAW) welding arcs. Both use an inert gas but MIG has a consumable electrode; whereas, TIG requires a side feed of a

filler metal when needed. The TIG is usually operated DC, except for aluminum welding, where it may be operated in AC mode. They measured the luminance value through different shade number filters as well. He explained that the reflected radiation had to be measured at actual sites and this included reflections from the floor, walls and curtains. They employed an Optronic Model 742 scanning spectroradiometer which scanned between 200-900 nm at 5 nm intervals, but this scan was very slow compared to the fluctuations in the arc under measurement. They also used a MES 30,000 CCD instrument which covered the 180-1060 nm spectral band with a 0.02-0.09 nm resolution. Unfortunately, the MES 30 000 had noticeable stray light and was not highly portable with its weight of 50 kg. The short emission time of welds and the moving welding spot gave them measurement challenges, and the dust, humidity and temperature working in closed spaces made good measurements difficult. They performed a study of aluminum arc welding in Finish shipyards in 1997. The MIG emissions showed a strong line at 280 nm, whereas the TIG showed stronger lines in the visible. The advantage of the CCD spectrometer was the ability to capture spectral emission lines.

58. Dr. Kirsti Leszcynski, Finish Radiation and Nuclear Safety Authority (STUK), Helsinki Finland, spoke on solar UV monitoring. She explained that in 1995, they conducted an European intercomparison of broad-band meters for solar radiation. They had characterized two spectroradiometers, an Optronic Model 742 and a Bentham Model DM 150 and 36 Solar radiometers, a Yankee UVB-1, 2 Vital meters and one German Scintec meter. She showed very good agreement between Green's model and their measurements. She estimated that although they could achieve uncertainties of about 3 % in the laboratory with a spectroradiometer and a standard lamp, but when moved outdoors, they estimated an overall uncertainty of 8% for outdoor solar radiation for their spectroradiometer and 11% for the broad-band meters. She noted that there were discrepancies of about 6-8% in the UVR between NIST, NPL and PTB which led to uncertainties in anyone's outdoor UV measurement. She showed how several successive calibration lamps from NIST varied about 3% over the past decade. She concluded that twice yearly calibration of a field radiometer should be made even though some of her data showed drift of less than 1%, but she noted that the cosine correction was stronger for the MgWO4 meters than for the Scintec meter. She showed spectral response of a large number of broad-band meters where the variation was large only at wavelengths greater than 330 nm. She showed solar-zenith-angle correction factors for the field meters, and by applying these they could achieve very small uncertainties.

59. Dr. Charles ("Rocky") Booth, Biospherical Instruments, Inc., San Diego, CA, described multi-band radiometers used for dose, cloud and ozone determinations. He stated that his class of instruments were well characterized for use in solar monitoring, but could not be directly used with other spectra without a lot of work. His company's Model GUV 511 had four channels peaking at 305 nm, 320 nm, 340 nm and 380 nm. A teflon diffuser mounted on a quartz input window provided a good cosine response. Standard lamps could not be readily used, but instead they used a reference, well calibrated spectroradiometer to constantly monitor solar radiation and the calibration algorithm for each GUV 511 was then derived by constant intercomparison. The calibration rested on the assumption that there were not atmospheric constituents which significantly altered the solar spectral distribution. It appeared that all of the

intercomparisons had been achieved in San Diego on the Pacific Coast. Nevertheless, his estimated variability was within 0.2 æW/cm2. He also showed quite good with TOMS satellite measurements. They had 2-3% agreement for periods of time as great as 1 year, but there had been problems of one channel changing by as much as 10%. He argued that his device could be used to back calculate a biological dose if the desired action change were to be changed.

60. Karl Schulmeister, Austrian Research Center, Seibersdorf, spoke on the importance of specifying the aperture and FOV over which MPEs are to be averaged. He explained that the aperture indicated the area over which the radiant power is averaged. He explained that the 7-mm aperture used in many guidelines and standards were based upon the pupil of the dark-adapted eye, and larger apertures could be used where the irradiance was rather uniform. He showed a table from the draft IEC 60825-9 which had erroneously applied the small laser type of averaging apertures despite the fact that ICNIRP and other incoherent standards had recommended 25 mm, etc. He explained that for radiance measurements, the angular averaging acceptance angle was important. He emphasized the great importance of not mixing up the angular subtense à of the source with the FOV of the measuring instrument. Although in radiometry it is always appropriate to measure source radiance with a FOV smaller than the source angular subtense à, this is not the case for optical hazard evaluation. He gave an example of how this averaging angle varied for larger viewing durations but was fixed at 11 mrad for 10 s based upon eye movement studies and was recommended by ICNIRP for durations up to at least 100 s.

61. Teresa Goodman, NPL, Teddington, England, spoke on calibration of a broad band radiometer. She noted that instruments had different purposes and some were to follow an action spectrum, but others were designed simply to isolate a portion of the spectrum, e.g., a UV-A meter or to be used only with one type of source. This led to a real challenge for the calibration laboratory. She described spectral mismatch errors and explained how this could lead to big errors with some types of sources. She also noted that many glass filters transmit radiation above or below the defined passband and this should be checked with blocking filters. She then switched to the FOV problem, as shown in an example of an LED array. Deviations in radiometer linearity frequently occur at high irradiances, even though the radiometer may have a linear response over several decades. She then discussed standardization activities underway in the CIE, the European Community UV network program and other groups to standardize on calibration techniques for special purpose meters such as erythemal meters for solar radiation.

62. Andrew Pearson, National Radiological Protection Board (NRPB), Didcot, England, spoke on their experience over a number of years with quality control of broad-band meters. Their experience had been to detect errors as great as 50% with some broad-band instruments. This led them to bring a spectroradiometer to their rooftop monitoring site to perform erythemally effective UV measurements and used the broad-band meters to determine how constant the irradiance was during a spectral scan. He looked forward to a UV calibration protocol to come from a WMO committee.

63. Ulf Wester, Swedish Radiation Protection Institute, spoke on the measurements and safety of sunbeds. He explained that there

was a European Standard, Euronorm 60-335-2-27 for sunbeds which specified the maximal amount of UV-B and UV-A for four types of sunbed or sunlamp systems. He described the European and Swedish requirements for marking of lamps used in sunlamp products. In Sweden, it was required to have a license to have commercial type suntanning products. They had a real problem with replacement lamp bulbs. Indeed many solaria owners wanted to find more powerful lamps, and the radiation protection community wanted to lower limits.

64. Frank Wilkinson, Commonwealth Scientific and Industrial Organization, Australia, spoke on the level of confusion relating to testing sunscreens relative to a laboratory solar simulator. He showed the range of possible spectral irradiance scales for a "standard sunlight," and none really seem to be accepted. He showed how a solar simulator was applied on the back of a volunteer. He noted that if a UV solar simulator was increased over the outdoor value of 5 mW/cm2 were increased by 50 fold to 250 mW/cm2 it should be nearly intolerable, but a realistic upper limit would be of the order of 150 mW/cm2. He cited the paper of Dan Berger, Specification and design of solar ultraviolet simulators, J Invest Dermatol, 53:192-199 (1969) which had been the referenced solar simulator until the filter was changed to allow a small amount more UV-B radiation. He showed how the inner and outer spectral bounds proposed by Robert Sayre were slightly exceeded by one Solar Light simulator which he measured. The problems he saw with solar simulators were that : one needed a high UV irradiance level requiring removal of the visible in order not to overheat the skin. Yet the ratios of UVA to UVB were not at all similar to real outdoor simulators. Almost all were using the Solar Light Solar Simulators. He noted that by far most of the UV erythemal effectiveness comes from the UVB, so some errors in the UVA is not so important. He concluded that current standards allow too wide a variation in the UVB and almost no control in the UV-A. He speculated that there may be some nonlinearities in dose response in the UV-A.

65. Robert Sayre, President of Rapid Precision Testing Laboratory, Cordova, TN, spoke on testing of solar simulators for safety and SPF testing of sunscreens. He showed a photographs of the Solar Light single-port solar simulator and their Multiport system. The emission aperture of the multiport was 8 mm and the older units had apertures varying from 7 to 10 mm. He noted tat the MUT SU-5000 from Germany and the Dr Mueller units from Germany had higher UV-A irradiances than 250 mW/cm2. He had become very enthusiastic about the Optronics 754 Spectroradiometer to take to the field. Using GAF chromic film which has a linear dose-rate response, he was able to map spatial non-uniformities. He stated that the solar spectrum would not meet the COLIPA standard and that others were quite good. He argued if a CIE standard is adopted, it would be desirable to have requirements for more UVA-1, specify beam uniformity, irradiance limits and total amount of radiation. Furthermore, he thought there should be a standard on how to certify the solar simulator, i.e., the stray light, the bandwidth and number of points, etc.

66. Janocz Beer presided over a discussion of the posters. With regard to Poster #11 on the measurement of a number of lamps in accordance with ANSI/IESNA RP27 standard, there was a discussion of tungsten-halogen lamps. There was interest in diode-array spectrometers, but these were shown to be poor in the short UV region. There were several questions relating to UV biofilms,

and it was noted some deviation from the erythemal action spectrum [although closer to the ACGIH/ICNIRP action spectrum]. It was noted that the Polish standards were more restrictive than ACGIH for UV-A radiation. Dr. Beer noted that the poster submitted by Bhat from India was quite interesting in relation to cataract. The Stoev poster on UV transmittance of fabrics was interesting because it identified the errors introduced by fluorescence.

67. A panel was chaired by Colin Roy to discuss any remaining questions or issues and to recommend future work for CIE Division 6. This brief session also served to reconvene the Division 6 working meeting. Dr. Elizabeth Weatherhead, NOAA, Boulder, CO (who had been delayed presented an unable to present her paper earlier), gave some general remarks on the UV Index and the great importance of communicating the risks of sunlight exposure to the general public. There were several suggestions that CIE Division 6 provide more guidance on sunlamp testing and the solar simulator definition. There was a proposal relating to applying the photometric f1' concept to UV meters. CIE TC 6-45 was working on this in conjunction with CIE TC 2-47 and Dr. Teresa Goodman (the liaison between the two TCs) stated that the UV meter problem was probably too complex to apply this f1' concept, but this would be discussed. Dr. Sliney urged attendees to request to participate as a member in TC 2-47 and Dr. Goodman seconded this view. Betsy Weatherhead and Colin Roy explained that a WMO working group was developing UV measurement criteria, and it was recommended that this effort be a joint effort with Division 6 and Division 2, or perhaps to establish a new CIE TC 6-49 on UV global measurement.

68. New work items recommended included a TC to be chaired by Prof. Wolbarsht on "Infrared Cataract." This report would complement the TC report on UV Cataract and would raise the issue of photochemical vs. thermal damage mechanisms; members would include Dr. Okuno, Prof. Anthony Cullen, Prof. Sasaki, Dr. Eva Lydahl, Prof. Bjorn Tengroth, Prof. Martin Mainster and Dr. Joseph Zuclich. There was also a recommendation to establish a TC on photodegradation of pharmaceuticals by Dr. Joseph Piechocki; this was seconded by Don Forbes. Dr. Piechocki would serve as chair of the TC. It was also noted that it would be desirable to have activities in photochemistry such as solarization testing of materials. Dr. Sliney suggested that those interested in such subjects should submit specific proposals with proposed TC chairmanship, membership and terms of reference (or scope).

69. In closing remarks, Dr. Sliney, thanked all the participants and asked for an accolade for the organizing committee and administrative support staffs at NIST and USACHPPM who had played such an important role in making the Symposium a success. He noted that this was the first joint effort between the CIE and ICNIRP and he thought the great success would no doubt lead to future collaborations. In addition, he explained that the book originating from the MORH Symposium would not just be a proceedings, but edited to be a reference manual on MORH. All speakers and attendees would receive a copy of the MORH book. He warned those speakers who had not submitted their manuscript, to urgently do so.

DAVID H. SLINEY, Ph.D.