UNIVERSITY OF KOBE, JAPAN
INTERNATIONAL MARITIME HEALTH ASSOCIATION

Test Methods for Color Vision in Seafarers with Navigational look-out duties

Expert workshop, Kobe, 20-21st January 2014

Background

Seafarers with navigational look-out duties have been required to have their colour vision assessed for over 100 years, ever since red and green navigation lights were introduced and collisions and other incidents were attributed to the deficiencies in colour vision that are present in approximately 8% of males. The methods of testing used have long been controversial, not least because there are several types of deficiency and their severity varies from near normal colour perception to complete loss of colour vision.

Individual maritime states set their own standards and procedures for vision testing for much of this period, but for the last twenty years there have been internationally recommended criteria published in the International Maritime Organisation (IMO) Convention on Standards for Training, Certification and Watchkeeping (STCW). This convention has recently been revised and is now progressively coming into force. Vision standards were made mandatory as part of this revision in order to improve the consistency of assessment worldwide and to make mutual acceptance of fitness certificates issued in other countries simpler. However, since agreement on the convention, parties to the convention have identified some practical difficulties with the vision standards and brought these to the attention of IMO. These have arisen because of the incompatibility of the mandatory standards with current national practices and because the range of test methods specified produce inconsistent results and often require high-level skills to use and interpret the results. In addition, some of the tests are no longer available commercially. Aspects of concern include colour vision assessment for look-out duties, the need for colour vision assessment in engineers, the lack of assessment methods for 'night blindness' and the fitness of those with monocular vision.

The IMO adopted the CIE (*Commission Internationale de L'eclairage*) Technical Report 'International Recommendations for Colour Vision Requirements in Transport' (CIE 143:2001) as the technical standard for colour vision assessment during the revision of the Convention. This recommends the use of a simple but demanding screening test, normally a plate test such as the 38 plate edition of the Ishihara test, which will correctly identify most of those with normal colour vision and those with a red-green colour vision defect, supplemented where required by access to more specialised confirmatory tests. The confirmatory tests that are recommended depend on the level of colour vision required for the duties a person performs on board. For CIE Colour Vision Standard 1 (Normal

Colour Vision), the confirmatory tests are used to identify any false positive results from the screening test as well as to confirm a pass when there is a suspicion that the screening test responses were memorized. For Colour Vision Standards 2 and 3, the confirmatory tests are used to assess whether a candidate with a colour vision defect has sufficient colour vision to perform their duties. Different confirmatory testing schedules are recommended for those with look-out duties and for those who need sufficient colour vision to correctly identify denotative colours on displays and colour coded items.

For those with navigational look-out duties on larger vessels CIE 143:2001 recommends three options for confirmatory tests:

1. A second plate test, of a sort different from that used for the initial screen. However many authorities recognise that this is not an entirely logical approach as the risk of misinterpretation of colours may be the same in both initial and confirmatory tests.
2. Testing with an anomaloscope. This test requires a high level of operator skills to use correctly and does not reliably predict performance on all colour related tasks
3. Use of a very demanding lantern test (where the person being tested has to correctly identify small red, white and green lights in a dark room). The lantern cited as an example is the Holmes Wright B, which has good face validity as it mimics ship navigation lights, but is no longer manufactured. This test is so demanding that around 10% of the individuals with normal colour vision fail it.

Because of objections by a number of countries to the implementation of the CIE colour vision criteria for lookout duties, IMO decided to suspend their introduction until the scope for adoption of some of the newer computer-based tests had been considered. The purpose of this workshop was to undertake this task, as expressed in these terms of reference:

1. To consider the basic principles of testing as given in CIE 143-2001.
2. To propose practical and cost effective methods to use in future.
3. To endorse these for presentation to IMO STCW 45 [now HTW 1].

<u>Organisation of the workshop</u>

The University of Kobe agreed to host the meeting and the International Maritime Health Association adopted it as one of its programme of workshops. IMO was informed of the workshop. They did not take part in it, but recognised its relevance to resolving the choice of confirmatory tests to be used for colour vision testing. The workshop programme was discussed with CIE Division 1 (vision and colour) and Division 4 (lighting and signalling in transport) who had approved 143:2001. Both divisions were supportive and recognised the need for revision of the document. They indicated that to do so a joint technical committee (JTC) of both divisions would need to be established.

Prof T Carter, of the UK Maritime and Coastguard Agency, The Norwegian Centre for Maritime Medicine and IMHA (who had worked with IMO on the medical fitness standards for seafarers in the STCW Convention, including those for vision), with advice from Prof J Barbur of London City University, led on programme planning and on the identification of international experts to invite. Prof M Furusho of Kobe University led on local organisation and on the identification of contributors from Japan. The programme for the workshop is given in Appendix 1 and the list of participants is given in Appendix 2. Because there was no funding available to support attendance a number of invitees were unable to participate, but many sent in their contributions and expressed a wish to continue to be involved in discussions.

The following outputs were identified prior to the workshop:

1. Given consensus, the draft text of an addendum to CIE 143:2001 would be endorsed. This would be submitted to the CIE Divisions 1 and 4 for their consideration
2. A full report of the workshop (this document) would be prepared and made widely available, once endorsed by participants.
3. A summary of the costs and skill requirements for making any new confirmatory tests available would be made.
4. Outline proposals for any further research required would be agreed.

<u>Presentations</u>

After an introduction from M Furusho, the local representative of the Ministry of Land, Infrastructure, Transport and Tourism, Capt. Sakamoto, welcomed the participants to Japan and to Kobe. T Carter then outlined the background to the workshop, noting the roles of IMO and CIE, as outlined above. He also presented information on the diverse approaches to confirmatory testing for colour vision used in maritime countries. Additional comments were made by Dr P. Janna of Transport Canada, whose administration was facing problems with the new standards. The presentations that followed can be grouped and summarised under several broad headings

1. Studies of maritime visual performance requirements

The major justification for testing for colour deficiencies in those with look-out duties is to minimise the risk of collision and other incidents at sea. Testing of groups such as engineers is aimed at preventing incorrect recognition of denotative colour codes that could lead to safety-critical errors. This is a different visual task.

Dr J. Hovis, Canada, compared maritime incident reports from Canada, where relatively lenient colour vision criteria have been used for a number of years, with the UK, where normal colour vision is required. There was no evidence of any incidents that could be reliably attributed to colour deficiencies in the records reviewed from either country. Where vision was seen as a contributory factor to an incident, diverse aspects of visual function and cognition were noted. Bridge management issues were often cited as a contributing factor and the crew was often criticized for relying too heavily on direct visual information and not confirming their observations with radar or radio.

A contrasting approach was that from TNO Laboratories in the Netherlands (data provided but no representative present). They had simulated the effects of deficiencies in red and green colour sensitivity using video and still images of safety critical maritime tasks, both those involving lookout duties and those were correct recognition of colour codes was needed. These illustrated that distinguishing external coloured light signals was highly dependent on near normal colour vision and that red deficiencies had a particularly strong adverse effect. For colour code recognition there was often additional visual information that enabled correct identification, but less reliably so than when all features of the coding were perceived.

Dr K Kawamoto and M Furusho described the range of colour critical tasks undertaken by seafarers. They concluded by noting that, while test conditions could be fixed to isolate a single aspect of vision, this was not the case when working at sea. They emphasised that the main gap in knowledge related to describing and quantifying the visual task requirements for different types of work at sea and then devising test methods that are relevant to them. Another major contributor in assisting with correct recognition would be to provide other visual information in addition to colour to aid identification and so reduce the risk of errors.

Night-time visual requirements had been studied and were reviewed in a circulated paper from Wynn (UK) et al. Their study indicated the range of tasks undertaken by those with look-out responsibilities and reviewed the effects that these had on visual performance. It indicated the complexity of navigational look-out duties and the need to take a holistic view on all aspects of visual performance rather than concentration on a single aspect.

The overall conclusion was that there were few modern studies on the visual requirements for navigational look-out duties and none of those that had been performed provided the sort of information that could be used to determine whether any particular level of colour deficiency was compatible with safety during look-out duties. In addition, the differentiation in colour vision criteria for those acting as look-outs on ships of above and below 500 Registered Tons given in CIE 143:2001 was not considered to have a valid basis and did not accord with normal maritime practices.

2. Studies of visual performance in other settings

Several of the presenters of specific test methods had used visual performance data from other occupations such as flight crew, both military and civilian; air traffic controllers; train drivers, and fire fighters as the basis for determining appropriate test criteria. Thus the methodology for visual task analyses is well established but has yet to be applied to maritime work.

K Kawamoto, in his presentation, also drew comparisons from a wide range of visual tasks, such as clinical observation in medicine and the comprehensibility of coloured subway maps, to show differences in the understanding of coloured visual information by those with and those without colour deficiency. Dr N Ito, expanded on this topic by identifying the best colour mixtures to use in order to maximise comprehension by those with colour deficiencies. Prof. M Ayama's presentation on colour preferences among those with deficiencies also provided markers for the design of coloured signals and displays.

3. Principles of colour vision testing

Prof S Tsujimura outlined the role of different cone types in mediating pupillary responses to colour signals. His work demonstrated clearly that the absence of red / green chromatic signals in the retina can be detected using the pupillary colour responses and that in principle this technique could be used to detect and assess those with congenital colour deficiency.

J Barbur described other aspects of visual performance and discussed how disability and discomfort glare and the loss of functional contrast sensitivity at lower light levels can affect visual performance and also colour perception in occupational settings. In a separate presentation he identified and discussed the importance of the various factors that contribute to variability in colour perception amongst both normal subjects and those with congenital colour deficiency. These include both fixed traits such as the presence or absence of functioning cone pigments, the effects of variant cone pigments, changes in the relative numbers of long and middle wavelength cones in the retina, variation in their optical density and finally the effects of normal aging. He related these factors to the validity of different test methods that aim to assess the class of colour vision (i.e., normal trichromacy, deutan- and protan-like deficiencies or acquired deficiency) and to quantify the severity of colour vision loss.

4. The practice of colour vision testing

One of the most complex aspects of the use of colour vision test methods for decisions on fitness to perform safety critical tasks is the point at which the boundary between pass and fail should be set. Prof B Cole, one of those who had drafted CIE 143:2001, provided a written commentary for the meeting. He indicated that the intention of the drafters had been to ensure that those with look-out duties had 'normal colour vision' free from any deficiency. If this was still the goal he then proposed a framework for testing based on the use of the more demanding current tests, but with a full clinical ophthalmological colour vision assessment if the person challenged these findings. The detection of any abnormalities using clinical tests would lead to failure.

Dr M Rodriguez-Carmona presented her work on the development of pass-fail criteria for airline pilots and subway train drivers. This was based on the use of the CAD test and on validation against the most colour demanding visual tasks identified for the jobs in question. She found that a degree of deficiency was compatible with safe performance. She had also looked at the scope for using the characteristics of each Ishihara test plate and the total number failed as indicators of the type and severity deficiencies. This approach did not provide a valid method. Results from 746 subjects were presented. These showed that in order to screen out all those with congenital deficiency one must allow no errors. Because of the sensitivity of Ishihara plates, the zero errors approach also leads to classifying 19% of subjects with normal colour vision as abnormal. As the number of incorrect plates allowed for a pass is increased to ensure that all normal subjects pass, an ever-increasing number of abnormal subjects also pass with no guarantee that they are safe to carry out the colour-related tasks involved with the same accuracy as normal trichromats. In practice variations in the administration of plate tests such as Ishihara also contribute to errors and there is scope for inaccurate assessment because of the ability of motivated subjects to make use of other cues that allow them to memorise plate numbers in advance.

It was noted during the workshop that a number of maritime countries, probably the majority, have been using less demanding tests, which enable some of those with mild deficiencies to pass, for a long period without any apparent problems. As some of the newer tests enable the type and severity of deficiency to be quantified, the adoption of 'normal colour vision' could probably no longer be justified in terms of equity, unless valid studies of colour vision demands for lookouts were undertaken that indicated the need for normal colour vision. Screening for 'normal colour vision' would be a way of ensuring adequate performance, but at the expense of denying some fully capable individuals the opportunity for employment at sea.

The timing and frequency for colour vision testing was also discussed. The current maritime requirements are for testing at least every six years. In practice, where confirmatory tests have been done, the seafarer often carries a certificate to this effect and so is not necessarily re-tested at this frequency. The logic of six yearly tests is unclear, given that the common red/green deficiencies in males are stable genetic traits. However experience in the aviation industry has shown that the requirement for repeat testing has identified a number of pilots who passed earlier in their careers but have now been discovered to have colour deficiency when new tests such as the CAD are used! The percentage of subjects with acquired loss can be quite large over the age of 60 years, often, in this pre-selected population, exceeding the percentage of subjects with congenital deficiencies. All subjects with acquired loss examined with the CAD test showed both red/green and yellow/blue loss. The only condition where yellow/blue loss was greater was age-related macular degeneration. A retest later in life, say at 50 years, which includes yellow/blue evaluation as well as a repeat test of other visual functions would be biologically rational but in practice more frequent screening in the course of routine seafarer examinations is more practicable in a population that is often mobile and may not be in permanent employment.

5. Evaluation of specific test methods

There have been a number of studies of individual test methods, usually either by comparison between them or by comparison with recognised clinical testing protocols. A systematic review of published reports on the performance characteristics and validity of different tests has been undertaken by Dr K Bailey. This is unpublished at present but was circulated to participants. It provides sensitivity and specificity data on the main current test methods. Dr N Milburn has evaluated many of the commonly used tests in relation to the changing visual demands in civil pilots, especially the move from incandescent to LED signal lights. This study, which was presented by J Hovis, both showed the rationale for assessments being made by reference to relevant occupational tasks and also provided information on the validity of a range of test methods.

Two candidate methods for which information was available to participants: the TNO Test from the Netherlands and the Chroma test from UK have yet to be evaluated on occupational populations. These were not discussed further. There was also a discussion on the available lantern tests and their performance. It was noted that the Holmes Wright B test (one of those listed in CIE 143:2001) required essentially normal red / green colour vision for a pass. The other lanterns all enabled a proportion of those with minor deficiencies, especially for those with green deficiency, to pass. J Hovis provided written information on his assessment of a number of lantern tests in comparison with the Farnsworth D-15 test and this indicated that most of the available lanterns were more demanding than this test.

J Barbur presented information on the other confirmatory tests listed in CIE 143:2001. Anomaloscope results reflect the equality of the colour match and in the majority of cases provide conclusive information on the class of colour vision involved. The use of either the match midpoint or the matching range as a measure of the severity of colour vision loss was less convincing, with many deuteranomalous and protanomalous subjects producing a matching range smaller than the average normal trichromat. Alternative plate tests to Ishihara, also listed as an option, would tend to confirm the original plate results rather than adding new information. Some such as Richmond HRR could be useful, both because it will detect yellow/blue deficiencies and because the design of plates makes memorization prior to testing more difficult.

Three computer-based tests that had been validated for aviation and, in one case, for some other tasks, were presented.

THE CONE CONTRAST SENSITIVITY TEST (Dr J Gooch)

This was developed for the US Air Force and has since been commercialised. Its aim is to accurately identify individuals with normal colour vision, as well as to detect, categorise and quantify colour vision deficiency among aircrew and aircrew applicants in order to ensure adequate performance, both in relation to cockpit displays and external visual tasks. It scores performance by presenting red, green and blue letters of decreasing contrast on a plain iso-illuminant gray background and measures the individual's threshold for correct detection of each colour. It is presently designed to run on a portable Netbook laptop, which also has the software needed to record and analyse findings. The Netbook has its colour balance fixed, but periodic calibration checks are needed for quality control and to ensure luminance and chromaticity remain at pre-programmed factory settings.

Compatible, integrated software from the same commercial supplier provides a full range of other visual function tests on the Netbook hardware, including spatial acuity, contrast acuity, mesopic acuity and stereopsis. Testing is adjustable to near and far distances. The sensitivity of the test, as presented, for detecting and categorising colour deficiencies was 100% in a population of 40 with green deficiency, 7 with red deficiency and 2 with blue deficiency, who comprised all those found to be colour deficient in a group of 1446 USAF pilot training applicants. It was >99% specific. It was also possible to derive a measure of the degree of deficiency present. The test takes less than five minutes to perform and, as it is automated, can be performed by a person who has had a brief training session. This test aims to accurately detect, categorise, and quantify both normal and abnormal colour vision, but does not presently provide validated task-based performance pass / fail limits that would allow some of those with mild colour deficiency to pass. However, it has been designed for this purpose and the US Air Force is presently conducting human performance studies to determine such limits.

THE COLOUR ASSESSMENT AND DIAGNOSIS (CAD) TEST (Prof J Barbur)

This test employs, colour-neutral, flickering background noise with 'square-outlines' of coloured stimuli buried in this noise and moving diagonally across the flickering background. The method is based on findings from camouflage studies, which showed that these conditions isolate the use of colour signals. The subject has to detect the direction of movement of the coloured stimulus and, when they do so successfully, the colour strength is reduced and becomes harder to see, conversely when movement is not detected correctly the colour is strengthened. This test uses a dedicated desktop computer and a stable, 30 bit, 24" colour display that supports other vision tests. It requires periodic calibration. It is a highly flexible system that enables most aspects of colour vision to be assessed and any loss of sensitivity to be measured. In practice it is used with an initial screening phase, taking less than 2 minutes. This phase makes use of the upper 'normal' age limit data incorporated in the test and identifies reliably those who have no red / green and yellow / blue colour impairment. If any impairment is detected then two further tests are performed to establish the severity of red / green and yellow / blue colour vision loss and the class of deficiency involved. The two additional tests take ~ 12 minutes to perform and also detect and quantify automatically the presence of acquired deficiency. Staff with no specialised skills can be rapidly trained to administer the test.

The CAD test has been extensively validated for use in aviation, where the required level of colour vision has been quantified with pass / fail limits of 6 and 12 standard normal CAD units for deutan- and protan-like subjects. The test also incorporates pass/fail limits for London Underground train drivers and air traffic controllers. As the test quantifies severity of loss, a pass/fail cut-off needs to be established from studies of the visual requirements when colour-related tasks are involved in a specified occupational setting, other than if used to detect everyone who has less than normal performance. Sensitivity and specificity for this test in relation to detection of congenital colour deficiencies are stated to be 100% for subjects less than 50 years of age. Although age-corrected limits are employed, the sensitivity and specificity may be slightly less than 100% for older subjects, when changes in colour vision can be affected by reduced retinal illuminance and other factors. The costs for hardware and software are higher than those for the CCT because of the high precision display and calibration equipment employed. The test does, however, provide great sophistication in terms of analysis of colour deficiencies and also for clinical applications. The test can be used to establish whether a person has the level of colour vision needed to meet the visual demands and performance requirements within specified occupations, as well as to rapidly screen for normal colour vision prior to employment.

The Acuity-*Plus* test designed for photopic and mesopic assessment of spatial vision, also supplied for use on the same hardware, is useful for assessing spatial vision in subjects with early stage cataracts or after corneal refractive surgery.

COLOR DX (WAGGONER COMPUTERIZED COLOR VISION TEST) (Dr M Rings, US Navy)

This test is a desktop, laptop or tablet based assessment using Waggoner color vision plates. It comprises a short screening test and a longer (<10 min) diagnostic test that uses de-saturated plates to assess the degree of deficiency. A Farnsworth D-15 test is also built in. Validation has been done on 208 military subjects, 48 with colour vision deficiency. It proved to be 100% sensitive and specific for screening when compared with the Nagel anomaloscope and this was better than other current tests. It is commercially available at $ 800 for software and $1300 for tablet and calibrator. While it is essentially a plate test it is proof against subject and tester variability and can also determine the level of deficiency for red, green and blue parts of the spectrum.

<u>Discussions</u>

All the tests currently used for colour vision assessment in seafarers have limitations, but an initial sensitive and stringent screening test, such as the Ishihara plates test, followed by the use of a confirmatory test for those who fail on the screening can reliably separate out either those with completely normal colour vision, if the most the most demanding of the available confirmatory tests are used (CIE 143:2001 standard 1), or those without severe deficiencies if less demanding ones are adopted (CIE 143:2001 standard 2). None of the tests listed in CIE 143:2001 reliably quantifies the level of colour vision deficiency. Currently testing practice varies widely from country to country and it is not possible to state which practices are most appropriate for adoption internationally. It needs to be recognised that there are human and legal problems for any maritime administration if test procedures are changed, as some of those found fit by previous test protocols may now be found unfit, while those who have previously been declined for employment may now be found suitable.

There are no recent studies on the visual requirements for safe maritime look-out duties or for other maritime work where colour discrimination is needed. Without such studies it is not possible to determine which test methods and what sequence of testing strikes the right balance between maintaining a high standard of maritime safety and ensuring that those with minor degrees of colour impairment are not penalised unfairly for having congenital colour deficiency. This will only be resolved by visual task analysis in maritime settings and full assessment of severity of colour vision loss of the sort that has already been done for aircrew and for air traffic controllers.

There are at least three computer-based tests that have the potential to improve the quality of either confirmatory testing or even the totality of colour vision assessment. The CAD test is the most comprehensive and requires relatively costly dedicated equipment. It is, however, being adopted for civil aviation in a number of countries and so may become more widely accessible in future. The Color DX is a lower cost test that could increase the validity of existing testing procedures, but is directly based on isochromatic plates of the sort used in most initial screening procedures and so may be less acceptable for use as a confirmatory test, especially when the severity of the deficiency is being investigated – although it could be argued that it already complies with the second plate test option given as a confirmatory test option in CIE 143:2001. The CCT is intermediate in its potential and costs, and could be a valid initial screen or confirmatory test. None of these tests has been fully validated on seafarers, but a limited number have been studied using the CAD test, and this has confirmed the earlier assumption that the Holmes Wright B lantern can only be passed by those with virtually normal colour vision.

Because of the lack of studies of visual requirements for seafarers and given the ability of the computer-based tests to quantify the severity and nature of colour deficiencies those present concluded that they could not offer IMO an immediate solution to the problems that have arisen in some countries from the adoption of CIE 143:2001 into the mandatory code for the STCW Convention Manila amendments. The workshop has instead provided an appraisal of different options for new approaches to testing, with the proviso that none will be scientifically valid and fully satisfactory in the absence of up to date studies of the visual requirements for maritime look-out and other duties. See Appendix 3.

In practice the requirements for colour vision cannot be isolated from other facets of vision in seafarers. Aspects such as dark adaptation, acuity under low contrast conditions, peripheral vision and glare all need to be taken into account. A study covering all these aspects would both provide more valid criteria for use in colour vision testing and be an economical way of gathering additional information about these other aspects of the visual requirements for seafaring than would a series of separate investigations of each facet.

Prof Ayama, the associate director of CIE Division 1, indicated that both Divisions 1 and 4 were keen to take work forward on a revision of 143:2001. She reviewed the procedures for doing so. These involve the preparation of a paper for both Divisions setting out the background and requirements for this work. The two Divisions, provided they agree to this proposal, would then create a joint technical committee to undertake the revision. She identified a number of those present as suitable members for such a committee. One aspect that would need early resolution arises because CIE 143:2001 covers all modes of transport and not just seafaring. The proposals for revision would have to address this.

<u>Actions</u>

1. Give an oral presentation on the outcome of this workshop to the IMO HTW Committee in mid February. This will be based on the options appraisal at Appendix 3. This cannot be a written paper because of the timetable needed for translation. The Committee will only be able to note the recommendations at this stage, but could choose to take implementation forwards by correspondence between meetings. There could be advantages in presenting the need for research on visual requirements as a part of the IMO human factors programme rather than being seen simply as a matter of crew medical selection. **M Furusho, T Carter.**
   Post meeting note: a brief presentation was made. There was no discussion at the time. A full paper will be submitted to the next HTW meeting.

2. Prepare a full report of the workshop (this document). Once endorsed by participants it will be circulated more widely within the maritime and vision science communities. It will be posted on a relevant website, such as that holding the IMHA workshop reports. **T Carter, M Furusho.**

3. Consider publication of a summary of the workshop proceedings. The journal 'International Maritime Health' would be suitable, as it is read by those who currently conduct most seafarer vision checks. **T Carter.**

4. Prepare a report for CIE Divisions 1 and 4 detailing the need for a review of CIE 143:2001 and proposing ways to take this forward. **T Carter**

5. Develop protocols for studies of colour and other vision requirements in seafarers. These would need to be performed in ways that would enable valid criteria for vision testing to be developed as has been done within the aviation environment. The scope for modification to work practices and to the visual information available to seafarers should also be investigated. Such work will require funding. **Defer allocation of responsibilities until initial discussions with IMO and CIE have taken place.**

Tim Carter
7th March 2014.

Appendix 1.

Workshop programme

Workshop on vision testing in seafarers:

- **revision of colour vision test methods - research priorities for visual task analysis.**

Kobe Port Tower Hotel, Japan. 20-21 January 2014

Organized by Kobe University, Graduate School of Maritime Sciences, International Maritime Research Centre and by IMHA (International Maritime Health Association).

Day 1: 20th January 2014

Background. Chair Prof Masao Furusho

10:00-10:05

Prof. Furusho. Introduction and welcome. Objectives of workshop

10:05-10:10

Welcome speech by Captain Toshiaki SAKAMOTO. The Ministry of Land, Infrastructure, Transport and Tourism, JAPAN

10:10-10:30

The background from IMO perspective. Adoption of CIE 143-2001 Dr. Tim Carter (IMHA, UK). Practical problems with use of CIE criteria. Dr Peter Jana (Canada)

10:30-10:45

Discussions with CIE on Review of CIE 143-2001. Tim Carter, with comments from CIE panel members present.

10:45-11:00 Discussion – objectives of workshop and organisation of task ahead.

11:00-11:10

Agreement on members of drafting group to produce proposed addendum to CIE 143-2001 and on members of research interests group.

Background presentations. Chair Prof Masao Furusho

11:10-11:25

How seafarer colour vision testing is done in practice at present. Tim Carter (UK, International Maritime Health Association)

11:25-11:40

The Japanese approach to colour vision testing for STCW. "Background of the Applicable Table for Testing Seafarer's Colour Vision in JAPAN" Kaoru NAKAMURA, Tokyo Women's Medical

University, Japan. Masao FURUSHO, Kobe University, Japan

11:30-11:45

A Look at Recent Accidents at Sea and Colour Vision Deficiencies. Jeff Hovis (Canada).

11:45-12:15

Variability in normal and deficient colour vision: relevance to colour assessment within occupational environments. To include include lanterns, pseudoisochromatic plates tests, anomaloscopy. John Barbur (UK).

12:15-12:30

Video of effects of colour vision impairment in maritime settings. Material provided by TNO (Netherlands). See paper: Dynamic Simulation of Color Blindness for Studying Color Vision Requirements in Practice. Marcel Lucassen & Johan Alferdinck;

12;30-12:45

A new approach to setting pass-fail limits for colour vision in other transport environments. Marisa Rodriguez-Carmona (UK).

12:45-13:00

"Preference for color enhanced images assessed by color deficiencies" Miyoshi Ayama (Professor, Dr. of Engineering Dept. of Advanced Interdisciplinary Sciences Graduate School of Engineering, Utsunomiya University, Japan)

Discussion: non-presented background papers. Chair Tim Carter

14:15-14:30

1. Field investigation into maritime colour vision requirements. Marcel Lucassen & Johan Alferdinck (Netherlands)

14:30-14:45

2. Night-time Lookout Duty: The Role of Ambient Light Levels and Dark Adaptation. Tony Wynn, Peter A. Howarth, Bert R. Kunze (UK).

14:45-15:00

3. How consistent are the results of occupational colour vision tests?. Kevin Bailey (UK)

Recently developed test methods: basis, validation, costs, skill requirements.

Chair Tim Carter

15:30-15:45

1. Review of data provided on TNO vision screening test. Tim Carter

15:45-16:00

2. Cone contrast sensitivity test. John Gooch (USA)

16:00-16:15

3. CAD test. John Barbur

16:15-16:30

4. US Navy Waggoner tests. Matthew Rings (USA)

16:15-16:30

5. Chroma test. Chris Hogg (UK). (Not present, information supplied)
6. Jeff Hovis to give presentation from Nelda Milburn (USA).

16:50-17:30

Conclusions of day 1

Comparability of test methods and appropriateness as additions to list in CIE 143-2001. - costs and skill requirements for use of each test method

Day 2: 21 January 2014

09:30-10:00

Review of first draft consensus statement. Tim Carter to lead

Text for addendum to CIE 143-2001.

10:00-10:30

Open session for discussion or additional presentations

A. Research interests group 1030: 11:45. Masao Furusho chair

10:30-10:45

What are needed as the visual function on the duties at sea? Ken-ichiro Kawamoto, Kawasaki University of Medical Welfare, Japan

Masao Furusho, Kobe University, Japan

10:45-11:00

Appropriate methods for assessment of visual performance (Colour vision, photopic and mesopic spatial vision, scattered light and glare). John Barbur

11:00-11:15

A Linear Summation of L- and M-cone Signals in the Pupillary Pathway. Sei-ichi Tsujimura, Kagoshima University, Japan

11:15-11:30

Standardization of Colour Combinations for People with Colour Deficiency. Nana Itoh; National Institute of Advanced Industrial Science and Technology(AIST)

Practical aspects of the use of changed methods for individual visual assessment of fitness to perform Ken Sagawa: Professor, Japan Women's University.

11:30-11:45

Summary of proposals for development and research and the mechanisms for taking this forward.

B. Drafting group 1030 onwards. Tim Carter to lead

Revise draft in light of discussions of first draft of text for addendum to CIE 143-2001.

11:45-12:15 Plenary: review of second draft.

13:15-14:15

Research proposals. Make proposal.

Agreement on projects and approaches to development and research work and discussion of funding possibilities.

14:15- 15:30 or completion

Concluding session. Tim Carter

Outputs from workshop and next steps.

Thanks to host and farewell.

Appendix 2

Workshop participants

Masao FURUSHO	Kobe University, Japan
Tim CARTER	UK Maritime and Coastguard Agency, Norwegian Centre for Maritime Medicine.
Peter JANNA	Government of Canada
Ken-ichiro KAWAMOTO	Kawasaki University of Medical Welfare, Japan
Sei-ichi TSUJIMURA	Kagoshima University, Japan
Hung-Shing CHEN	National Taiwan University of Science and Technology
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Appendix 3

<u>Workshop consensus document: brief for presentation to IMO HTW committee and for subsequent circulation.</u>

<u>Test Methods for Colour Vision in Seafarers with navigational look-out duties</u>

<u>Workshop supported by Kobe University, and within the International Maritime Health Association (IMHA) programme of maritime health workshops, held on 20-21 January 2014</u>

The terms of reference for the workshop were:

1. To consider the basic principles of testing as given in CIE 143-2001.
2. To propose practical and cost effective methods to use in future.
3. To endorse these for presentation to IMO STCW 45 [now HTW 1].

Because of the complexities of the topic there is no sound basis on which to make a single recommendation to IMO in the short term that is both scientifically valid and meets the above requirements.

There are a number of promising new candidate protocols for computer-based screening and diagnostic tests, of the sort noted in IMO STCW 7/Circ. 20 Para. 5, for use as confirmatory tests for colour vision in those seafarers who have failed the initial screening test procedures. However the adoption of these depends on defining the test criterion that it is appropriate to use for navigational look out duties at sea. The recommendations in CIE 143:2001 specify 'normal colour vision' but as these newer tests are capable of measuring the class and degree of any colour vision deficiency it is important to specify the level of abnormality which is still consistent with safe performance of navigational look-out duties.

It would be rational for any changes to take account of the biological features of colour impairment. For red and green defects almost all cases result from stable genetic traits that are commoner in males. Hence testing at the start of work at sea is highly relevant, while the currently required re-testing every six years has no rational basis. There is, however a small reduction in colour sensitivity with age and a single retest later in life could be justified. Yellow and blue defects are less directly relevant to navigational look-out but may have some marginal effects. The majority of these are acquired and associated with age-related eye conditions. A single re-test perhaps at age 50, if one of the computer-based tests is used, could usefully include assessment of yellow and blue impairment.

1. In the view of this workshop the only valid long-term solution would be to undertake studies of the colour vision demands of navigational look-out duties and derive evidence-based criteria for fitness from these. If this approach is adopted it would also be desirable to review

the appropriate colour vision criteria for engineers and electro-technical officers, as there are marked discrepancies in national practices. Any such study would also need to look at other visual demands, such as acuity and dark adaptation in maritime settings at the same time as these will interact with performance on colour vision tests. The evidence base for all seafarer vision standards is ancient or non-existent and such investigations would enable it to be updated to take account of modern job demands. *This approach, which was favoured by the workshop because it has the potential to provide a scientifically valid approach to testing and one that is optimal in terms of fair treatment of seafarers. It could best be taken forward by means of a review of CIE 143:2001 by a joint technical committee (JTC) of the two appropriate CIE Divisions, with input and support from those who participated in the Kobe workshop. The JTC would also specify investigative needs, but these would require the maritime sector to fund a development project over several years to establish the required evidence base. The aim of this work would not be to make standards more demanding but to make them fit for the purpose they are intended for, ensuring that vision is appropriate to the demands placed on it while working at sea.*

2. The workshop considers unacceptable any approach based on a review of existing practices among maritime nations with the adoption of a minimum acceptable criterion that accords with the least demanding standards that are now in use. The workshop participants would, however, encourage collection of information on current national practices as well as associated reports on any incidents attributable to colour vision deficiency worldwide.

This would be essentially a 'political' rather than a science-based solution and input from vision scientists and the CIE would be limited to confirming which test methods and pass/fail criteria met this lowest acceptable common standard. Information collected on national procedures and on incidents could inform the work of the CIE committee

The workshop considered whether it would be possible to make recommendations to IMO to enable the suspension of the Table A-1/9 colour vision criteria, authorised in IMO STCW 7/Circ. 20, to be lifted in the near future. This would be an interim measure pending the completion of the review of colour vision requirements. Two options were suggested:

3. Cease to use the CIE standard 1 for colour vision for look-out duties and endorse the use of CIE standard 2 for all look-out duties and not just for those on ships of less than 500 g.r.t. It appears that, despite earlier agreement to use the CIE standards, many states currently only test for compliance at the equivalent of standard 2.

This would be a move away from the 'normal colour vision' benchmark used in CIE 143:2001. It is a 'political' solution that might well satisfy the concerns of those states that objected to the text of this table. However it *does not have scientific validity in the absence of data on visual demands.*

4. Maintain the 'normal colour vision' benchmark used in CIE 143:2001 for navigational look-outs on larger vessels but to recommend validated computer-based tests* for use as options in addition to the currently listed confirmatory methods, which are based on using a visually demanding lantern, anomaloscopy or a second approved plate test.

This would make little change to the current decision-taking process but would overcome the objections to those confirmatory methods that are no longer available or which need specialised operators. The costs would be those of providing these new tests as centres appropriate to the needs of the country. Cost of test equipment varies from c $1,000 to c $10,000. But these could be reduced as these methods become more widely available.

However if IMO does not want to adopt an interim solution and is prepared to delay a decision until one of other of the longer term options given above are agreed then IMO STCW 7/Circ. 20 could remain in force for a longer period, although this might endanger mutual acceptance of medical certificates after the coming into force of the convention in 2017.

Two solutions that the workshop does not support either because they are impractical or would not secure international consistency are:

5. Abandon the concept of 'confirmatory testing' that is unique to colour vision and accept that, for new recruits to jobs, with navigational duties a pass must be secured at the current CIE levels using the Ishihara or similar plate tests. Recommend to parties to the Convention the option of moving to one of the three computer-based tests listed below, with the threshold for each set to correspond with the plate test pass.

This would maintain maritime safety standards, but at the expense of some candidates being denied job opportunities. The computer-based tests would provide a more valid result than plate tests, but arguably not one that was as lenient as those inherent in 1 or 3 above. Such an approach would need suitable test facilities to be available for all seafarers if computer-based tests were to be used.

6. Move table A-1/9 from the mandatory A code of the Convention to the recommended B code, thus leaving parties with the freedom to adapt test methods to national circumstances.

Existing practices could be maintained but mutual acceptance of medical certificates would become more problematic if there was such flexibility for a key safety-critical standard. It could be argued that, while there were no benefits for maritime safety, it would not be reduced. This would *not address the problem of replacement of obsolete and irreplaceable equipment, such as test lanterns, but it would allow individual parties to introduce new methods at their own discretion.*

Given that IMO seeks a solution that is evidence-based, scientifically valid and fair to those tested, the workshop participants recommend that is done in partnership with CIE. A number of participants would be willing to contribute their expertise to this work. But the task will not be free from costs.

*

1. CAD Test, City University London. www.city-occupational.co.uk
2. Cone Contrast Sensitivity Test, www.innovasysi.com (Site currently being revised to include information on this test)
3. Color DX Test, Konan, USA. http://colordx.com