84-127

DEC 23 1987

Director
Division of Safety Research
NIOSH
944 Chestnut Ridge Road
Morgantown, West Virginia 26505

Dear Sir:

The following comments are submitted for your consideration in the writing of the Final Rule for 42 CFR Part 84. My comments I feel must be addressed in your Final Rule. See attached list of comments and support documents.

I believe that NIOSH has finally moved this whole issue of Respiration Certification to the point for public dialogue. I want to see NIOSH moved on to a Final Rule when they have resolved the various technical problems and related issues.

Sincerely,

Thomas H. Seymour
Fire Protection Engineer

Enclosures

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OD, DSR, NIOSH

1. I recommend that §84.1, purpose, be revised to include all respirator users. Suggest a revision as follows:

   §84. 1 Purpose.
   "... for the certification of respirators for worker protection from airborne contaminants or hazards."

2. I support the definition of IDLH contained in §84.200; This definition is excellent. The OSHA Directorate of Safety Standards would use this definition immediately in 1910.120 (proposed) and 1910.146 confined space standard (within draft form) if the definition were in a final rule.

   Until this proposal, NIOSH has consistently misdefined the term, i.e., in the Pocket Guide to Chemical Hazards and in Subparagraph 3 of Niosh Respirator Decision Logic.

   In both documents a 30 minute exposure is specified for an exposure to cause none of the undesired effects. The Pocket Guide makes clear this exposure is 30 minutes at the IDLH level with no respiratory protection.

   The zeal to protect by providing "some margin of safety in calculating the IDLH" is admirable, but there is no harm at all. This cannot be called IDLH without redefining the entire language. Regardless of what guidelines are used for setting on IDLH level, such a criterion must not be included in the definition of the term; that makes for paradox, not definition.

3. I support the requirement of §84.22(e) which requires eyepieces and facepieces to provide a level of impact resistance and penetration equivalent to conventional safety eye and face protection. This negates the need for additional eye and face protection to be used with a full facepiece respirator or with a hooded or helmet respirator.

   Failure to incorporate this language would leave the wearer inadequately protected and require the use of uncomfortable secondary protection which would also interfere with proper mask/face seal or may otherwise cut down on the wearers field of vision.

4. I support the requirements of §84.223, Body harnesses. In particular we support the requirement that the harness not melt when exposed to temperatures of 400 F for 30 minutes. This requirement addresses a problem which as occurred during actual use in firefighting activities. However fabric components of firefighter PPE are usually tested at 500 degrees F for five minutes and should be specificed as the minimum performance if the 30 minute test is not going to be retained in the final.

5. I suport the requirement of §84.220(f) and §84.232(e) which require that respirators be compatible with the use of safety glasses since eye protection may be necessary in many working conditions where 1/2 and 1/4 facepiece respirators are used.

6. I support the requirements of §84.248-11, tests during low temperature operation. These provisions address problems which have occurred in the past when respirators were used in cold environments.

7. I support the shock and vibration tests which are included in §84.248-12. These tests also address problems which have occurred due to vibration of respirator equipment during transport to an accident. Duration of vibration test is not specified. Perhaps 3 hours on each axis? total of 9 hours?

8. I support the flammability test requirements for facepieces contained in §84.248-17 since respirator users (rescuers, fireman, etc.) may encounter a brief flame exposure during their use of the respirator. This test has been used in West Germany for years for respirator approval and it is needed in the USA as well.

9. Corrosion testing criteria should be added. Tests should include salt spray test similar to those specified in NFPA 1981 (1987).

10. Criteria for improved communications SCBA should be developed. Minimum test evaluations should be made for speaker diaphrams such as being able to understand wearer five feet away by a person with normal hearing.

see follow on pages for additional comments and suggestions.

U.S. Department of Labor

Occupational Safety and Health Administration
Washington, D.C. 20210

Reply to the Attention of:

NOV 15 1985

MEMORANDUM FOR REGIONAL ADMINISTRATORS

THRU: JOHN B. MILES
Director
Directorate of Field Operations

FROM: STEPHEN J. MALLINGER
Acting Director
Directorate of Technical Support

SUBJECT: Use of Bureau of Mines Approved Gas Mask Canisters

We have received several inquiries concerning the use of Bureau of Mines approved gas mask canisters. These canisters were approved under the Bureau of Mines Schedule 14F for protection against many highly toxic substances such as hydrogen sulfide, hydrogen cyanide and phosphine. All these canisters were approved for concentrations far above their respective immediately dangerous to life or health (IDLH) values and none of these compounds has adequate odor warning properties for the respirator wearer to detect excessive facepiece leakage or sorbent breakthrough.

Although the Mine Safety and Health Administration (MSHA) and the National Institute for Occupational Safety and Health (NIOSH) have extended the expiration date for the Bureau of Mines approved gas mask canisters, NIOSH indicated that they could not conduct quality control testing on these canisters to assure that the performance meets the certification requirements.

In view of the above facts, it is concluded that the Bureau of Mines approved gas mask canisters for protection against hydrogen sulfide, hydrogen cyanide and phosphine may not provide adequate margin of safety to the respirator wearers. Their use for other than emergency escape is not acceptable.

for canisters. see attached letter of Nov. 15, 1988.

-5A-1

Comments from the Occupational Safety and Health Administration on the Proposed 42 CFR 84

— without it being reevaluated.

84.2(b), Expiration of Certification

There should also be a provision that all certifications expire after 5-10 years. This will prevent the same device from being approved for over 30 years as we now have. ~~Bureau of Mines approvals should be terminated immediately.~~ Besides, many Bureau of Mines approved canisters are acceptable for protection against substances with poor warning properties eg. hydrogen cyanide and phosphine.

84.11(d), Specimen Respirators

According to 229(e) at least six units will be needed and should be specified here. Since the respirators will be made by automated processes, the specimen submitted should be identical in all respects, or the same as, not identical "in all significant aspects." The latter is far too loose.

84.14(added), Waiting Period

One of the major drawbacks of the present system is that manufacturers can keep resubmitting essentially the same respirator in rapid fire order. To alleviate this we believe a mandatory waiting period is appropriate to allow for proper development work. Hence we suggest this paragraph be inserted "If NIOSH denies an application or withdraws a certification under this part, the manufacturer may not resubmit for certification the same or similar respirator for a period of six months after the denial or withdrawal, or after the conclusion of any appeals, whichever is later."

84.23, User Notification Plan

This paragraph should require manufacturers, as a condition of continued certification, to actually use the plan whenever the manufacturer learns of a defect (including information from NIOSH) or has a certification modified or withdrawn.

84.32(a), Extensions

The extensions now are open ended. A limit is needed and we suggest that 90 day extensions are adequate.

84.41, Labeling

Too often the actual end user of the simpler respirators never see the approval labels because they are on packaging that is removed and discarded at a distribution point. Therefore this paragraph should specify that one or the other form of the label should be on or accompany each unit of all air-purifying respirators. It could be on a card or part of instructional materials (see next item).

84.50, Instructional Materials

Most disposable respirators have instructions printed on the carton. Since these respirators are packaged 50 or 100 in a carton, and the carton is generally thrown away as the respirators are distributed, a requirement should be established that instruction materials must be packaged with each individual respirator.

84.60, Modifications

The current language for this section will prevent the introduction of new respirator models. Any new models will be classified as major modifications to escape the requirements of any new performance standards. Therefore, we strongly recommend that both (b) and (c) be changed to read, in part "... standards in effect on the date of application for certification of the major modification...."

84.70(c), Failure to Notify

This paragraph should be modified to make use of modified 11.23 by new wording, "Failure of a manufacturer to provide NIOSH and users with the notification required in sections 11.22 and 11.23."

84.70(k), (added) Withdrawal of Certification

A very important cause for withdrawing a certification should be inadequate results from NIOSH testing of respirators. Therefore, a new paragraph (k) should be added, "NIOSH testing in accordance with subparts O-Z on units obtained from normal distribution channels fails to corroborate the manufacturers findings for the two (six) respirators submitted in accordance with 84.11(d)."

84.70, (additional cause for withdrawal of certification)

This section should also have a provision to the effect that all certifications of a manufacturer will be withdrawn if the manufacturer is found to be marketing a respirator as certified when in fact it is not or is found to be using a certification label that is not approved by NIOSH.

84.71, Withdrawal of Certification

Stop-sales orders should be issued to manufacturers to prevent more defective products moving to market during the withdrawal proceeding.

84.200, Technical Definitions

a. The present definition of "breathing tube" does not distinguish it from high pressure airlines and needs the words "at near ambient pressure" inserted after "respirable air." For completeness a separate definition is needed for "air-line" such as "a hose used to supply compressed breathing gas to a respirator."

b. The definition of "canister" or "cartridge" will be very confusing because any disposable mask including those without any cartridges, canisters or separable filters will be called a "cartridge" mask.

c. Since the application of these regulations goes beyond OSHA's regulations, the definition of "ceiling limit" and "permissible exposure limit" should include reference to standards and recommendations other than OSHA's such as those of AIHA, ACGIH and ANSI.

d. "dBA" needs to be defined in terms of the use of a "ANSI type II sound level meter."

e. The standard temperature and pressure used as a reference in defining "gas" must be stated because there are several "standard" conditions in common use.

f. The definition of IDLH should refer to something other than radioactive materials such as carcinogens to avoid the confusion that mention of radiation causes.

g. The definition of "Service Time" does not distinguish it from shelf life and should be changed. Also, it should refer to an air-purifying "element" not "device."

h. The proposal does not contain a definition for disposable respirators. By choosing not to distinguish disposable respirators from others, NIOSH is asserting that there is no difference in fit capability or in lasting fit integrity. In view of data in the OSHA respiratory protection docket, this is not a justifiable assertion. The distinction between ~~certain~~ disposables and other respirators should be made.

84.220, General Construction Requirements

a. Field of vision, glare, and chemical compatibility of the lens of the full facepiece with other chemicals should be considered ~~as~~ for testing requirements.

b. There should be a requirement for the manufacturer of positive pressure respirators to install facepiece pressure indicators. If the facepiece pressure consistently indicates negative, the use of the respirator should be discontinued.

84.220(j), Skin Irritation

To reduce the possibility of skin irritation by the mold release compounds or residual molding compounds from which the facepiece is formed, as well as to avoid the transmission of communicable diseases through manual handling during manufacturing, all respirators should be washed and sanitized before they reach the end user.

84.226, Inhalation and Exhalation Valves

Either of these valves must be able to be sealed or blocked easily by the wearer to perform a positive or negative pressure test. No respirator should be approved if either a positive or negative pressure test (qualitative test) cannot be easily performed to check for faceseal leakage.

84.228, Noise

Proper construction requires the deletion of the "and" appearing after "airflow" and the addition of "the respirator" after "when."

84.232(a), Sizing (negative pressure respirators)

This draft proposal would allow a manufacturer to sell the facepieces they have already, no matter whether they fit a majority of users or not. This provision probably resulted from a compromise at the ANSI ad hoc subcommittee discussions. We believe that if a manufacturer cannot provide a model with a series of facepiece sizes that will fit at least 95% of the population as specified by LANL, the model should not be accepted for approval unless it is a special facepiece to fit extremely large or small faces.

84.232(b), Panel Selection

The measurement of facial sizes is prone to error and variation. A detailed method should be prescribed by NIOSH in an appendix to the regulations or NIOSH should certify persons who make these measurements.

84.232(e), Test Hardware

The aerosol size and concentration inside the test chamber should be verified periodically. Detailed methods should be specified in an appendix.

84.232(f), Exercise Regimen

The test exercises proposed for quantitative testing do not involve sufficient movement by the test subject to adequately determine leakage rates. These same test exercises are used in normal quantitative fit testing, and have not been shown to correlate at all to the levels of protection found during workplace testing. This has been thought to be because the exercises don't represent the types of movements workers perform on the job. The test exercises NIOSH proposes do not involve much real movement, such as would be caused by jogging in place, or walking on a treadmill. Treadmill tests at 80 percent of maximum work capacity should be performed on PAPRs, SARs, and SCBAs.

84.232(g), Data

Leakage assessment should be based only on the average of the peaks in the concentration profile inside the mask.

84.232(h), Analysis

It is not clear whether only one test is required or whether retesting is permitted or not. If retesting is not permitted, manufacturers should be required to submit to NIOSH a continuous uncut strip chart for all fit tests performed.

84.232(h)(2), Leakage Ratio

It is not clear why a "one" is subtracted from the reciprocal of L to calculate R.

84.232(h)(5), Upper Leakage Limit

The exponential part of the leakage limit expression is improperly typed so that it appears to be "L" times 10 to the X power.

84.232(j), Performance Criteria

a. The fit factors shown in the table are inadequate. They result in respirators that are marginal at best or inadequate for use under current practices in many cases. From our own experience, a good fitting respirator can obtain a fit factor of at least 1,000 and many facepieces now on the market can meet this level. The draft represents a lowered standard and a set of requirements substantially less than the current state-of-the-art.

b. It is generally agreed that the relationship between fit factor and the actual use protection factor is about 10 to 1. Using this as a basis, half-mask respirators would become inadequate for their current use (in any atmosphere up to 10 times the applicable limits) if filter penetration and facepiece leakage are both allowed to be 1 percent.

c. It is not clear here or elsewhere in the draft what are the applications of low, medium and high efficiency filters. This needs to be clearly described. At the very least the use of the low and medium efficiency filters will substantially alter the present accepted rules for selecting respirators.

d. We do not believe that a filter as bad as 5% leakage is useful or acceptable for respiratory protection today.

84.233(b), Maximum Leakage

Leakages as high as 1% and 2% are excessive. Leakage rates as low as 0.001 are achievable.

84.235, Powered Air-Purifying Respirators

Powered air-purifying respirators (PAPR) are generally used for highly toxic aerosols at high concentrations. A low efficiency filter may lose its effectiveness when dust loading is increased. Unfortunately, the wearer cannot detect whether the penetration of the filter has increased to an unacceptable level. Therefore, only PAPR's with high efficiency particulate filters should be approved.

84.236, Mouthpiece Respirators

The major limitations of the mouthpiece respirators are low service life of cartridges and no eye protection. These two limitations will significantly reduce its effectiveness during escape. Since many portable lighweight escape SCBA's are available, there is no reason to approve any product with such marginal usefulness.

84.240, SCBA

a. This part does not discuss whether buddy breathing devices would be acceptable or specifically approvable. We believe they are acceptable and criteria for testing them should be developed.

b. Most respirator manufacturers do not make air cylinders, and there is no testing requirement for air cylinders in this draft. The air cylinders should not be considered as part of the SCBA assembly for approval purposes. NIOSH should specify a type or types of air cylinder that are to fit all approved SCBA's. A similar situation is that tires on new cars are not guaranteed by the car maker but by the tire manufacturer. NIOSH could develop certifying criteria for air cylinders and make the cylinder a separate item of approval.

c. There should be weight limitations for all SCBA's. NIOSH should at least keep the same present criteria as found in 30 CFR Part 11 in this final rule.

d. There are some new SCBA's in which the mode of operation can be switched between open and closed circuit. Such an apparatus may fit one set of test criteria but not both, so consideration should be given to innovative types of SCBA.

e. The hyphenated section numbers should be eliminated for the sake of clarity.

84.246, Hand-operated Valves

Some positive-pressure SCBA's have a lever to enable the unit to operate in a negative-pressure mode for donning. Since the breathing resistance is lower at negative-pressure, some users may elect to leave the unit in that mode, which could be dangerous. Such two-way valve should not be permitted; the unit should be on or off.

84.248-3, Breathing Bag Test

Gasoline is not a commonly used solvent and the testing of breathing bags with saturated gasoline vapor is a potential fire hazard. Some more reactive and safer solvent should be used. A permeation test as developed by the ASTM for testing glove materials could be adapted for bag testing.

84.248-13, Use Tests

Most fire fighters criticize the service life of SCBA's because they do not last as long as specified. NIOSH should revise the work rate on these tests so that they are related to actual work situations.

84.251-3(a), Length of Hose

It does not seem relevant to certification to specify the length of hose sections. 30 ft., 40 ft., and 50 ft. sections would not appear to be hazardous or of much concern to a safety and health oriented certification. PRESSURE DROP CRITERIA SHOULD BE ESTABLISHED BELOW WHICH IT WOULD NOT BE ACCEPTABLE IN PROVIDING PROPER FLOW TO THE FACE PIECE.

84.251-3(b)(2), Air Flow

All but the last sentence of this paragraph is not needed (see item 60 and 61 below). There should be a stipulation that positive pressure units not drop below some specified pressure (for example 1 cm H_2O) during service.

84.251-3(c), Air Control Valves

If regulator longevity testing is required for SAR's, why is it not required for the SCBA? The cycling specification for the valve is not realistic--it would require 34 days around the clock or 100 work days to complete. Obviously the test will in fact be expedited. A more realistic specification is needed.

84.251-4, Harness Test

Since sudden loading doubles the strain caused by a given load it would seem appropriate to double the required pull.

84.251-7, Air Flow Resistance Test

This section needs an added subparagraph (c) essentially saying, "These specifications apply with any combination of air-supply pressure and length of hose within the applicant's specified range of pressure and hose length."

84.251-8, Air Flow Resistance Test

a. An additional subparagraph is needed as specified in 84.251-7 above.

b. If the system is limited by its ability to deliver air, the tests should use the higher required air delivery rates. This provision allows for zero bias in the pressure, yet most people expect the pressure to stay positive. Especially since some deterioration during use could be expected, the minimum pressure should be above atmosphere, for example 1 or 2 cm water.

84.251, Particulate Filters

Most breathing tubes of the SAR's and some PAPR's are lined with a plastic foam to reduce noise. An inline filter should be required to remove eroded plastic particles from the breathing zone of the wearer.

84.263, PAPR Flow Requirement

The proposal sets minimum air flow rates of 115 liters per minute for tight fitting PAPRs and 170 liters per minute for loose fitting PAPRs. These rates are unchanged from the current requirements. These low flow rates are one cause for PAPRs not achieving in the workplace the protection factors they are capable of. In a recent Lawrence Livermore study on PAPRs, it was recommended that the minimum air flow should be increased to 6 cfm in order to maintain a positive pressure at high work rates. NIOSH should consider raising the minimum flow rates for PAPRs in order to improve the performance of these respirators.

All PAPR's should be required to have an audible warning device to warn the wearer if the facepiece pressure goes negative for any period longer than 5 seconds. The alarm should only be turned off by the power switch of the PAPR. Since most battery packs do not function well in low temperature conditions, the tests should be conducted at $0^{o}C$ to determine adequate airflow and service life. In order to ensure the PAPR is operated at positive-pressure during actual work conditions, human tests should be conducted at moderately heavy to heavy workloads to measure facepiece leakage and pressure.

84.270-.271, Particulate Air-Purifying Respirators

There is no provision for testing filters against acid mist, oil mist, paint spray, or pesticides. There is no reason for not developing new testing criteria, just because the current methods have been severely criticized. In addition, how many units are to be tested according to the specifications of subpart V.

What is the basis for the three classifications, what are they protective against? The allowable penetration of 5% for a low efficiency filter is too high, a penetration of 2% is more appropriate. Because the exact relationship between filter efficiency and size is not well known or predictable, it would be more credible to use a larger particle (for instance 2 micron, AMMD) to test the "low efficiency" filter. Is the low efficiency filter supposed to be a surrogate for the present "dust" filter?

84.271(a), Particulate Respirators

All particulate filters should be color coded by filter type for easy identification. Colors should be established that will not cause identification problems for those that suffer typical color impaired vision problems. Most of those who have colored impaired vision are males. See National Bureau of Standard's reports NBSIR 83-2694 (April 1983) pps. 7-20. See p-12 for discussion of color impairment. NBSIR 86-3493 provides excellent for color criteria under various lighting conditions. See attachments for both documents

84.272(a), Air Flow Resistance

Air flow resistance tests are needed after each test in section 84.273 because too much buildup in breathing resistance is unacceptable.

84.273(a), Penetration Test

This unwisely implies that this test is not required for disposable respirators because they do not have separable filters and filter element holders.

84.273(b), Preconditioning Test

A dynamic conditioning test is most stringent and, therefore, more desirable than the static test. A minimum test time of 12 hours may be acceptable for conducting preconditioning.

84.273(d), Filter Test

The standard flow rate for testing should be 85 and 32 lpm. If filters are tested in pairs or trios, the total allowable penetration should be the same as that specified for a single filter.

84.273(e), PAPR

There is obviously an editing problem here: all of the subparagraphs are irrelevant to PAPR's.

84.273(f), Challenge Aerosol

It is not clear what the "100 ± 5 mg of the aerosol has contacted the filter unit" means. Does it mean the respirator filter or the back-up filter? If, as we assume, it means the respirator filter, the test is too short, being 6 and 16 minutes, respectively.

84.273(g), Challenge Aerosol

It is not clear whether a monodisperse aerosol is an adequate proxy for the polydisperse aerosols occurring in the workplace.

84.280(a), Maximum Use Concentrations

OSHA may change the PELs for the gases listed. Then these limits would conflict with OSHA policy. The maximum use concentrations should be changed to acceptable penetrations. Even as they are these values are suspect because they bear no consistent relation to values accepted as permissible exposures or IDLH levels. The parenthetical portion is redundant in view of the definitions earlier.

84.284(b), Cartridge Service Life Test

a. The cartridge test at 50% relative humidity (RH) when conditioned at 25% RH is meaningless compared to the actual use conditions. The cartridges should be preconditioned at 90% RH at a flow rate of 10 lpm for 16 hours for non-powered air-purifying cartridges and tested at 50% RH and 32 lpm within 10 minutes to avoid any water desorption from the carbon. The cartridges should also be tested as received at 90% relative humidity for service life at 64 lpm for non-powered air purifying cartridges. Service life test conditions for PAPR's should be adjusted similarly.

b. The various subparts as now written are unclear, duplicative and somewhat contradictory, internally and in relation to other parts of 314.

c. It is not clear exactly how may units are to be subjected to each of the specified tests.

84.284(d), Flow Rate

a. The flow rate specification contradicts 284(b).

b. The total penetration for cartridges tested in pairs and trios should be limited to the same value as for single cartridges.

c. It is not clear what is so similar between powered particulate respirators and non-powered vapor/gas respirators to induce using the same tests.

84.284(e), Conditioning

a. It is not clear why cartridges should not be tested immediately after conditioning as is specified for particulate filters.

b. Why is the conditioning for only 6 hours compared to 24 hours for particulates?

c. The use of six hours and eight hours implies two-shift staffing of the laboratory or that all the tests will be done in last two hours of the work day.

84.284(f), Service Life

It is not clear why "combination" cartridges should be only one-half as good as regular cartridges. Also see comment #86.

84.290, Gas and Vapor Air-purifying Respirators

a. The testing requirements for combination particulate and gas/vapor respirators are not specified. If the respirator is certified for the combination for these challenge agents, it should be tested at a mixture of such conditions to ensure they can perform as intended. The particulate filter part should be limited to a high-efficiency filter to provide maximum protection to the users. It is likely the electrostatic charges which promotes particulate collection on the low efficiency filters may be destroyed by the gases or vapors.

b. If the PAPR is certified for gases or vapors, it should be placed in that challenge atmosphere to ensure the functional parts of the respirator will not be damaged by the test gases or vapors. It should provide a minimum service of 2 hours so the worker does not have to change the filter elements too often to be practical.

84.295(f), Carbon Monoxide Canister

a. To be consistent with NIOSH's current policy of not certifying any canisters for gases without adequate odor warning properties, the carbon monoxide canister should not be accepted. Besides, the color indicator is merely a moisture indicator. It has no relationship to the service life of the sorbent.

b. It would appear that having footnotes "b" and "d" apply to the same line of the table is logically inconsistent.

c. How to define "imminent leakage" as stated in (f)(2).

d. It is unclear why CO canisters, alone, have no pretest conditioning unless it is a tacit admission that the end-of-service-life indicator is fundamentally flawed.

e. It is not clear why the highest percentage leakage is allowed for those canisters that are meant or allowed to be used in IDLH conditions.

84.301, Organic Vapor Cartridges

It appears quite unjustifiable to use a flat 1,000 ppm as a maximum use concentration in view of the widely varying toxicities and sorption efficiencies of the relevant organic gases and vapors.

84.306, Breathing Resistance Test

The breathing resistance tests should be run both before and after service life tests.

84.308, Service Life Test for Organic Vapor Respirators

a. The ANSI Ad Hoc subcommittee has discussed a replacement for carbon tetrachloride, a suspected carcinogen, as a testing agent. Some agreement has been reached on using a low molecular-weight and low-boiling point compound and a higher molecular-weight and boiling point compound as testing agents.

84.312(a)(2), Desorption

Testing criteria on desorption should be specified to ensure there is no immediate breakthrough when the respirator is used for the second day.

84.312(b), Intrinsic Safety

The meaning of "intrinsic safety" is unclear. If applicable this paragraph should refer to class X divison X hazardous atmosphere.

Other Requirements

a. Shock and vibration tests should be performed on all air-purifying elements to avoid broken filters and the channelling effect on sorbents.

b. Filters should be installed near the inhalation valve of chemical cartridge or canisters to prevent the inhalation of sorbent particles by the respirator wearer.

c. A requirement for stop sales orders when defective products have been found should be established.

d. Labeling with a lot number and manufacturing date should be required for all products. Model and serial numbers should be stamped or marked on major components of SAR, SCBA and full facepieces and on the harness of gas masks to facilitate recalls.

NBSIR 83-2694

Some Criteria for Colors and Signs in Workplaces

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
National Engineering Laboratory
Center for Building Technology
Building Physics Division
Washington, DC 20234

April 1983

Sponsored by
The Occupational Safety and Health Administration
U.S. Department of Labor
Washington, DC 20210

NBSIR 83-2694

SOME CRITERIA FOR COLORS AND SIGNS IN WORKPLACES

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U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
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U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, *Secretary*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

ABSTRACT

The use of safety-related visual displays such as signs and colors in workplaces is discussed. The discussion includes a review of relevant national and international standards for safety colors and signs. It also includes a review of measures of spatial resolution in human vision, as well as of color sensitivity and color appearance. In addition, research on the effectiveness of safety signs, symbols, and colors is reviewed. Based on the initial literature review, the appearance of safety colors under energy-efficient light sources was identified as an area for detailed research. As a result, a laboratory study was conducted in which the color appearance of 45 different color samples under five light sources including energy efficient ones was determined for seven subjects. The color samples were contained in four color series: standard safety colors; experimental colors; retroreflective and retroreflective-fluorescent colors; and fluorescent-only colors. The results indicated the existence of a set of colors which was more identifiable under all light sources than the current standard safety colors. This set contains a number of fluorescent and retroreflective colors, unlike the current safety colors. Recommendations are made for further research, including field research, to determine the effectiveness of the suggested color set on safety signs under an even broader range of illuminants. The need to assess color appearance under mixed light sources is also addressed.

Keywords: Chromaticity, color, color appearance, energy-efficient lights, illumination, light source, safety, safety signs, safety symbols, visual acuity, visual sensitivity.

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2. VISUAL REQUIREMENTS FOR SAFETY COMMUNICATION

2.1 BACKGROUND

A worker who moves around an industrial facility must be constantly aware of potential hazards in this environment. In general, there are three stages in the perception and reaction of people to workplace hazards. These include:

1) Awareness of the hazard
2) Recognition of the nature of the hazard
3) Response to the hazard.

Usually (but not always) stage 1 requires performance of a visual task by the employee. The most common visual task is the location and identification of a safety or warning sign (in addition to locating and identifying a potential hazard). Therefore, to alert a person to a potential hazard or safety message, one should locate a safety sign such that it: 1) attracts the attention of the person; 2) conveys information about the hazard; and 3) is located so that the person can respond in a timely and appropriate fashion (Chaffin, Miodonski, Stobbe, Boydstun, and Armstrong, 1978).

The ability of a sign to attract the attention of the worker assumes that the sign is VISIBLE. The question of sign visibility requires information about at least four sets of variables: the visual performance abilities of the observer, characteristics of the visual stimulus (or sign), characteristics of the illumination system, and optical properties of the atmosphere. The observer capabilities include: observer acuity, adaptation state, age, opacity of the lens and cornea, color deficiencies, and chromatic adaptation. Sign visibility requires knowledge of both the illumination system characteristics and those of the sign or visual stimulus. These include: illumination level, type and spectral characteristics of the illumination; as well as characteristics of the sign such as size, shape, contrast, color, location, size of letters and symbols, stroke width, stroke width-to-height ratio, legibility, and cleanness. The fourth set of variables includes those related to the optical transmission properties of the atmosphere within the line of sight, including haze, smoke, dirt, dust, or pollution.

In the present paper, the focus will be upon the visual performance of the observer and the properties of the visual stimulus and the illuminant. The reader is referred to Middleton (1963) and Douglas and Booker (1977) for a further discussion of the optical properties of the atmosphere, and to Howett, Kelly, and Pierce (1978) for a discussion of the use of flashing lights as warning devices. Visual performance of the observer will be discussed primarily in terms of spatial resolution including measures of acuity and contrast, and chromatic sensitivity. Similarly the properties of the visual stimulus will be addressed in terms of legibility and color. The illumination system will be discussed in terms of spectral transmission, color temperature, and potential color rendering capabilities.

2.2 MEASURES OF SPATIAL RESOLUTION IN HUMAN VISION

What type of detail can the human eye resolve in near and distant viewing situations? Although a person's ability to resolve detail can be altered by either near or far-sightedness, as well as by disease, some measures of general human visual acuity under "normal" viewing conditions may be summarized. The reader is referred to Thomas (1975) for a fuller discussion of these issues.

2.2.1 Specific Variables

Visual acuity, or the resolving power of the eye, is defined in terms of the smallest detail that the eye can resolve. The stimulus used to test acuity is usually either a black pattern on a white background or the reverse. In either case, lightness contrast is made as great as possible. The size of the test pattern is systematically reduced until the critical feature is just barely resolvable. The acuity threshold is then stated in terms of the angle subtended at the eye by the threshold critical feature. Visual acuity is defined as the reciprocal of the threshold, when the threshold is specified in terms of minutes of arc. Normal acuity is 1.0, corresponding to a pattern that is just barely resolvable and whose critical dimension subtends 1 minute of arc at the eye. Thomas (1975, p. 234) says "In Snellen notation, acuity is expressed as the ratio of the distance in feet at which a detail is resolved to the distance at which the detail would subtend 1 minute of arc. Thus, 20/10 indicates that a detail that is just resolved at 20 feet would subtend 1 minute of arc if viewed from 10 feet. The equivalent decimal acuity is 2.0." There are a variety of test patterns which are used to measure acuity. In general, the test pattern may be one of the six following types.

2.2.1.1 Minimum Distinguishable

What is the smallest point, line, or other shape that can be recognized on a contrasting field? Hecht and Mintz (1939) showed that when conditions are optimized, a threshold width of 0.5 seconds of arc was obtainable for a long dark line on a very bright background. This is more than two orders of magnitude (120 times) smaller than the traditional one-minute-of-arc acuity threshold, and was made possible by the great length of the line, and even more by the extreme contrast obtainable with an opaque object viewed against a self-luminous background. Much lower contrasts are achievable on painted signs, and the threshold in such a "real-world" situation is considerably larger.

2.2.1.2 Minimum Separable

This task is usually tested with two dark points or lines whose distance apart is gradually changed. The smallest distance between the two targets in which they are resolved individually is the measure of interest. Craik (1939) found that under ideal conditions, 0.5 minute of arc was the minimum separable gap that was resolvable.

2.2.1.3 Vernier Acuity

Vernier acuity may be defined as the ability to discriminate the break between two end-to-end lines that are slightly displaced laterally. Berry (1948) showed that such thresholds range down to 1 to 2 seconds of arc. Vernier acuity is not usually relevant to sign visibility.

2.2.1.4 Minimum Recognizable

This measure of visual acuity applies to the recognition of distinct shapes such as Landolt rings or Snellen letters. A Landolt ring consists of a black circle with one gap located at varying positions, similar to a letter "C". The ring is varied in size, maintaining strict proportions, to find the smallest gap that can be seen. Snellen letters are alphabetic characters which are reduced in size until they are barely legible. Threshold for this task (minimum recognizable) is based on stroke width, length of the letter arms, and width of gap between arms (Sloan, 1951).

2.2.1.5 Contrast Sensitivity

Another way of assessing the resolving power of the visual system, is by determining the minimum contrast needed to see a grating pattern (Schade, 1956). The word "grating" refers to a pattern of alternating light and dark bars. By reducing the difference in luminance between the light and dark bars, a "contrast" threshold may be obtained. The reciprocal of threshold is termed "contrast sensitivity". One common definition of contrast particularly as applied to gratings is the following:

$$C = (L_{max} - L_{min}) / (L_{max} + L_{min})$$

where:

C = contrast
L_{max} = luminance of bright bars
L_{min} = luminance of dark bars

This definition of contrast is also referred to as "modulation".

The number of light and dark bars (cycles) per degree of visual angle describes the fineness of the grating. Campbell and Robson (1968) provided illustrative data showing the contrast sensitivity versus spatial frequency for square and sine-wave gratings at two luminance levels.

2.2.2 Variables Affecting Resolution

The variables which affect a person's ability to resolve detail can be divided roughly into six categories: illumination level (luminance), retinal location, pupil size, spectral composition of the illuminant, orientation, and viewing distance. The effect of these different variables will be discussed to determine their impact on visual resolution.

2.2.2.1 Illumination Level

Acuity in general depends on the luminance of the background against which the dark target is seen (or the target luminance, if it is the background that is dark). In the practical case of reflecting signs, the dark portions of the display have measurable luminance, and that luminance is also relevant. Generally, acuity increases with illumination level and is better at photopic, rather than scotopic levels of illuminantion. The photopic luminance range begins at about 1 footlambert (fl), with good color discrimination occuring at levels above this.

2.2.2.2 Retinal Location

Many researchers (Ludvigh, 1941; Mandelbaum and Sloan, 1947; Sloan, 1968) have shown that acuity is optimal when the target is viewed by the central fovea of the eye. In the periphery, acuity increases slowly as the intensity of the illumination is increased. Under semi-dark (scotopic) conditions, when the rods mediate resolution, acuity is highest for targets at 4 degrees eccentricity (4 degrees from the central fovea, Mandelbaum and Sloan, 1947). Apparently, there is little relation between the distribution of the rods and scotopic acuity, as the greatest concentration of the rods is at about 20 degrees eccentricity. Maximum scotopic acuity may be as much as 10 times less than maximum photopic acuity, however (Brown, 1965).

2.2.2.3 Spectral Composition of Illumination

Of interest to visual safety requirements is the question of visual acuity under narrow-band versus broad-band illuminants. This question does not appear to be easily answered, since it appears to depend upon which measure of acuity is used. Narrow band illumination reduces chromatic aberration and might be expected to yield higher acuities. Shlaer, Smith, and Chase (1942) found improvements with monochromatic illumination when the measure was minimum visible acuity, while Baker (1949) found improvements when the measure was vernier acuity. However, Shlaer et al. (1942) found no difference between acuities measured in narrow-band and wide-band illumination for the Landolt ring measure of visual acuity.

Does acuity depend on particular wavelengths when narrow band illumination is used? According to Thomas (1975), if higher intensities are used, where acuity no longer varies as a function of intensity, and assuming a moderate pupil diameter, acuity does not appear to vary as a function of wavelength. (For very small pupils, where diffraction becomes the limiting factor, acuity appears to be higher for short wavelength illumination than for longer wavelength illumination.)

2.2.2.4 Orientation

Lines or striations that are oriented vertically or horizontally are seen better than lines which are oblique (Ogilvie and Taylor, 1958; Higgins and Stultz, 1948; Shlaer, 1937; Campbell, Kulikowski and Levison, 1966; and Watanabe, Mori, Nagata, and Hiwatashi, 1968).

2.2.2.5 Viewing Distance

As the viewing distance of the target changes, the lens of the eye changes shape, or accommodates, in order to focus on the target. In general, all eyes have a near point limit, such that signs or objects presented closer than the "near-point" cannot be brought into sharp focus. As a person ages, the eye steadily loses its ability to focus for near work; in other words, the near point recedes. In most people, the need for bifocals or reading glasses to overcome this loss is felt about age 40 to 50. Myopic (near sighted) eyes also have a "far point" focus for which targets presented beyond this point cannot be sharply resolved. Acuity suffers if the target is outside this resolvable range.

The reader is referred to Howett (1983) for a more complete discussion of a methodology for calculating legibility from visual acuity. Suffice it to say for the present paper, that Smith (1979) recommends a minimum letter height for 100 percent legibility of about 0.84 in. for a viewing distance of 10 ft and 2.1 in. height at 25 ft, or a letter height which subtends about 10 to 24 minutes of arc. No comparable recommendations exist for symbol size. The Howett paper provides a means of calculating letter size for observers with different visual acuities.

2.3 COLOR SENSITIVITY AND COLOR CODING

The ability of the human eye and brain to distinguish the color of objects is known as color vision (or chromatic visual perception). Not all people have normal color vision and the specification of safety colors should take this fact into consideration. Color vision defects will be discussed further in section 2.3.1.

The International Labour Office (1972, p. 323) states that: "From the point of view of occupational safety, colour vision is of great importance as many accidents are caused by lack of suitable lighting or by failure on the part of a worker to identify conventional identification colours, such as on electric cables, gas cylinders, pipelines, guide marks, control buttons of machines, safety devices, and limit signals."

The concept of the color of an object is not as simple as it might appear at first. In general terms, the color appearance of an object depends on three main variables:

A. The visual sensitivity of the observer at the moment the object is viewed;

B. The spectral reflectance (or transmittance) distribution of the object, dependent on the particular pigments or dyes that give the object its color; and

C. The type of illumination under which the object is viewed.

2.3.1 Color Sensitivity

Human visual sensitivity is mediated by two primary types of photoreceptors, the rods and the cones. The rods, which are located outside the center of the eye (central fovea) are extremely sensitive to light, being capable of detecting the presence of only one or two quanta of light (Cornsweet, 1970). They are, however, insensitive to color. The cones, on the other hand, are maximally sensitive to color and color differences. There are three cone pigments, with maximal sensitivities occurring at about 450 nm, 530 nm, and 560 nm (Hurvich, 1981).

In the United States (and Europe) about 8 to 10 percent of adult males (caucasian) and 0.5 percent of adult females (caucasian) are color defective, with variations in these percentages depending on the ethnic population studied (Rubin and Walls, 1969; Krill, 1972). There does appear to be some variation in the incidence of color defects in different countries and different ethnic populations, although such variation will not be discussed in detail here. Such persons may simply be missing one or more of the three photopigments, or they may possess an anomalous pigment. Thus, dichromatic observers have only two pigments, while a cone monochromat (extremely rare) only has one. A rod monochromat, also an extremely rare individual, has only the rod mechanism active so that both visual acuity and color sensitivity are drastically reduced (Hecht, Shlaer, Smith, Haig, and Peskin, 1948). The various dichromatic deficiencies are of particular concern in the workplace, however. Commonly occurring dichromatic defects are related to the absence of the red photopigment (protanopia) or the absence of the green photopigment (deuteranopia) (Vos and Walraven, 1970). The third, much rarer, type, tritanopia, is related to the absence of the blue photopigment. In addition to the loss of photopigments, another class of color defects--the most common type--is the anomaly, in which the person is still trichromatic, but the spectral sensitivity of one photopigment is shifted from the normal. Persons with these anomalies will perceive colors somewhat differently from the normal and discriminate colors somewhat more poorly.

Both protonomalous and deuteranomalous defects are generally more common than the comparable dichromatic defect (Rubin and Walls, 1969). Rubin and Walls (1969) give the following breakdown for the estimated 8.8 percent of the male population that is believed to be color deficient: 5 percent deuteranomaly; 1.3 percent protanomaly; 0.0001 percent tritanomaly; 1.2 percent protanopia; 1.3 percent deuteranopia; and 0.0001 percent tritanopia. Although tritanopic defects are extremely rare, (and occur equally among males and females), acquired color defects in which sensitivity to blue is lost (due to injury or disease) are more common. In addition, as one ages, one's lens and cornea yellow, thus reducing sensitivity to blue. Eye diseases such as cataracts and glaucoma also reduce sensitivity to blue. Lakowski (1969) estimated the percentage of acquired color defects to be about 5 percent of the population.

The practical effect of color deficiency is to cause observers to make abnormal color matches or confusions between colors. Because both major types of defects--protan (including protanopia and protanomally) and deutan (including deuteranopia and deuteranomally)--are concentrated in the red and green, confusions between these colors must be carefully considered. Blue-yellow confusions are rare, so that it is not economically practical to make any allowance for them in designing color codes. Work cited by Judd (1948) suggested that a red should be somewhat orange, while a green should be somewhat blue to reduce confusions by protans and deutans. The current standard colors for traffic light signals reflect this concern.

Dichromats, unlike trichromats, only require two primary colors to match any third color. As a result, they will see as identical entire ranges of colors that appear quite distinct to a trichromat (see figure 1). For example, protanopes (figure 1a) confuse reds and bluish-greens, deuteranopes (figure 1b) confuse purples with pure greenish-blues, and tritanopes (figure 1c) confuse blues and greens. Both full-fledged protanopes and deuteranopes appear to lack totally the perceptions that color-normal observers term red and green; they see the world only in blues and yellows (Judd, 1948, 1949). (This conclusion can never be certain, but is widely accepted as highly probable.) Tritanopes appear to have better overall color discrimination with defects in wavelength discrimination emerging only in the blue-green region (Smith, 1973). They are believed to see the world entirely in reds and greens. (It should be noted that color defective observers often can distinguish colors on the basis of luminance cues.)

As is seen in figure 1, the CIE chromaticity diagram (to be explained in greater detail in section 2.3.3) can be used to define the confusion lines for dichromats because the colors which appear to be the same to a particular type of dichromat all lie on a straight line radiating from a single point (Fry, 1944). This point is different for each type of dichromat. In addition to color confusions, brightness perceptions may also differ from normal in those with color defects. The most drastic change is that reds become very dark for protanopic and protanomalous observers.

One important aspect of the abnormal color perceptions of anomalous trichromats can be measured by the use of an anomaloscope, an instrument in which pure yellow light is matched by a mixture of red and green. The proportion of red to green needed for a match with yellow indicates whether the observer is "red-weak" (protanomalous), "green-weak" (deuteranomalous), or color-normal. Anomalous trichromats require three primaries to match a given color, but use different proportions than would a normal trichromat (Brindley, 1970). Thus, for example, pure yellow is seen at about 578.3 nm for a deuteranomal, 583 for a protanomal, and 576 nm for a color normal observer (Linksz and Waaler, 1968). While the color confusions of anomalous observers are somewhat similar to those of the corresponding class of dichromats, they do not involve the confusion of entire lines of color in the chromaticity diagram, as is found with dichromatic observers. Because of their prevalance, color confusions should be considered in designing a system of safety colors for populations not selected for normal color vision. In fact, because the common screening devices for color-vision defects are very far from fully effective in detecting anomalous trichomats, it is desirable to allow for red-green confusions even for populations thought to be screened for normality. Bailey (1965) suggests that such tests may pass as many as 75 percent of color-anomalous observers, for example.

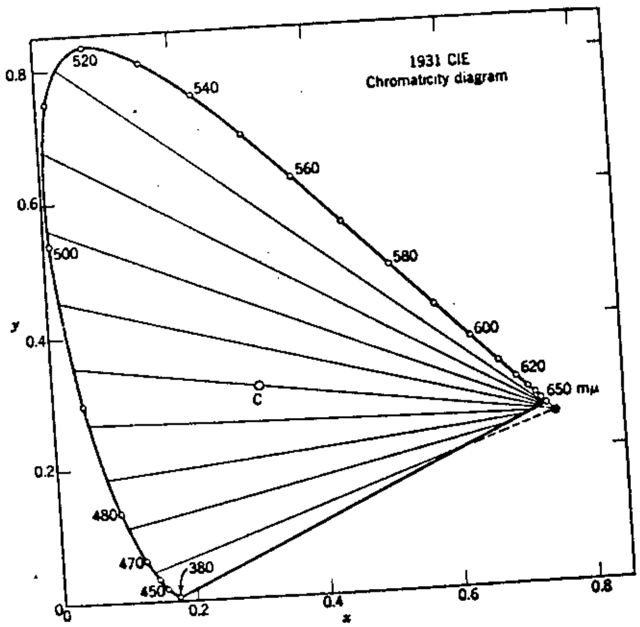

Figure 1a. Protanopic chromaticity confusions shown on the (x,y) chromaticity diagram

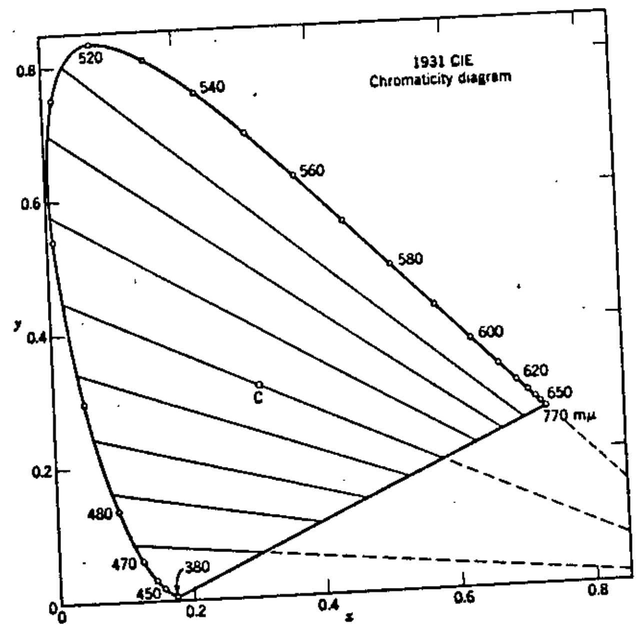

Figure 1b. Deuteranopic chromaticity confusions shown on the (x,y) chromaticity diagram

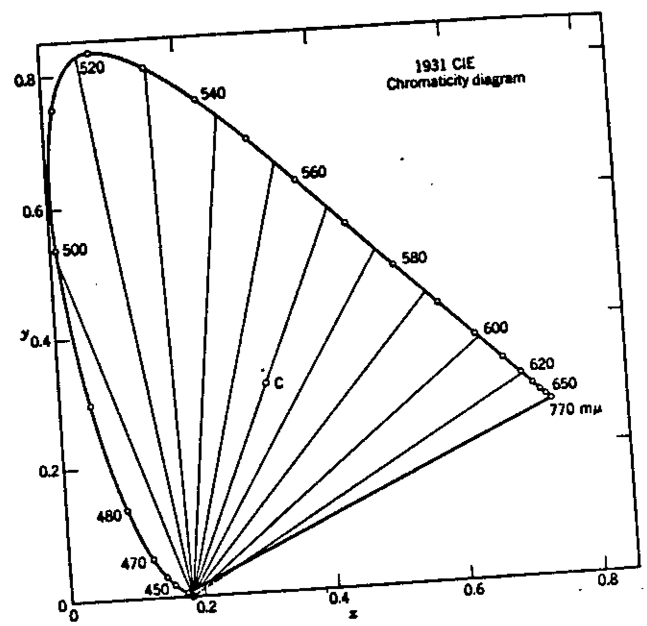

Figure 1c. Tritanopic chromaticity confusions shown on the (x,y) chromaticity diagram

Figure 1. Confusion lines of dichromats Figures reproduced from Judd and Wyszecki, Color in Business, Science, and Industry, Second Edition, (1963) with permission of John Wiley and Sons, New York.

2.3.2 Visual Adaptation

In addition to the physiological defects in color vision that have already been discussed, there are also normal moment-to-moment variations in visual sensitivity as a result of adaptation to different light sources. Three kinds of adaptation occur--light adaptation, in which the eye's sensitivity decreases rather quickly following a change to a higher level of illumination; dark adaptation, in which the sensitivity increases more slowly following a change to a lower level; and chromatic adaptation, in which the chromatic sensitivity of the eye shifts with a change in the color of the light source. Dark adaptation occurs when an observer goes from a brightly lit area, such as outside, to a dimly lit interior space. Depending on the darkness of the second space, a finite period of time, from 1 to 30 minutes, is required to attain the new higher level of visual sensitivity. During this time, because the scene being viewed is so much dimmer, the person can lose the ability to perceive objects and colors, until the eye adapts to the new luminance level. The reverse process of light adaptation, occurs much more rapidly--on the order of 1 to 2 minutes (Cornsweet, 1970). During this very brief transition, a person can be temporarily blinded, as happens when leaving a darkened theater on a sunlit day.

Chromatic adaptation occurs when a person spends time exposed to a light source of a particular color. When the person moves to an area lit by a different source, chromatic sensitivity will be altered progressively as the eye readapts (Hurvich, 1981). By way of illustration, suppose the initial light source is not pure white, but somewhat bluish. After exposure to this light for some time, the bluish stimulation fatigues the blue receptors of the eye proportionately more than the red or green receptors. Now suppose that the second source is pure white in color. Although it supplies equal stimulation to all three color receptors, it does not appear white to the blue adapted person. Rather, it appears yellow, because the blue receptors are fatigued and respond proportionately less than the red and green receptors. (Yellow is the result of simultaneous red and green receptor stimulation.) This result is temporary, however, because the white light is no longer disproportionately stimulating the blue receptors so that they recover their sensitivity, and the initially yellow-appearing light soon appears white. Thus, the effect of the chromatic adaptation process is to cause simultaneous changes in both sensitivity and color perception with the net result, after adaptation is complete, being some degree of stability in the perceived colors of objects under various light sources.

Marked chromatic adaptation will occur to a narrow band illuminant such as low pressure sodium whose dominant wavelength of 589 nm stimulates the red photoreceptors most strongly, the green receptors somewhat less strongly, and the blue receptors not at all. As a result, color perception is noticeably distorted during the first few minutes of subsequent exposure to a "white" light. There is an initial greenish-blue cast to everything because the blue receptors have remained highly sensitive, while the red receptors have become highly insensitive and the green receptors are in between.

2.3.3 Specification of Color Appearance

For a color to be seen as such, the light source shining on the surface must supply light of the appropriate wavelength. Thus, a "red surface appears red because it selectively absorbs wavelengths other than red, and it reflects more of the long wavelengths than of those in the middle or short wavelength end of the visible spectrum. Sources, surfaces, and media that are not differentially selective in the wavelengths they send, reflect, or transmit to the eye are seen as 'achromatic' rather than colored. They appear black, gray or white" (Schiff, 1980, p. 35). Note, however, that the red object cannot preferentially reflect long wavelengths if no long wavelengths are supplied by the light source. The worst type of light source for general illumination is a monochromatic (one wavelength) source; no object, regardless of its reflectance spectrum, can send any light to the observer's eye other than that one wavelength, since no other wavelength is there to reflect. Consequently, use of a monochromatic light will drastically alter the appearance of a colored object compared with "white" light. To deal with the problem of the way in which a light source can alter the perception of color, the CIE (1974) developed a Color Rendering Index (CRI) for specifying the color rendering properties of a light source. The IES (1981, p. I-8) defines color rendering as "the effect of a light source on the color appearance of objects in conscious or subconscious comparison with their color appearance under a reference light source." The Color Rendering Index provides a "measure of the degree of color shift objects undergo when illuminated by the light source as compared with the color of the same objects when illuminated by a reference source of comparable color temperature" (IES, 1981, p. I-8). The IES mentions that the CRI does not yet completely account for chromatic adaptation or color constancy, but that it does provide an agreed-upon means of comparing lamps for color rendition.

Specification of exactly what is meant when one gives a name such as "red" to a color even under ordinary daylight is not easily done. Does one mean "red", "magenta", "pink", or "burgundy"? How can one specify "red" so that another person can understand and reproduce the intended color? To address this problem, a number of color specification systems have been developed. Major systems for specifying object colors include the Munsell system, the ISCC-NBS color names, and the CIE Chromaticity diagram. Each will be discussed briefly in turn.

The Munsell color system organizes a set of 1600 color chips into a three-dimensional solid. Hurvich (1981, p. 275) describes it this way: "The individual chips are ordered into a three-dimensional color solid with a vertical black-to-white axis. HUES are arranged in equal angular spacing around the central axis and CHROMA (saturation) is the distance of a chip from the central axis at any given VALUE (lightness) level." Specifications for particular Munsell colors are given by three sets of alphanumeric characters which specify hue, value, and chroma.

The ISCC-NBS system of color names is a coarser subdivision of object-color space than the Munsell system. The ISCC-NBS system is based on the use of simple color names, easily understood without training. The blocks in color space corresponding to the ISCC-NBS color names are defined in terms of Munsell notation. Kelly and Judd (1976) discussed the idea of a Universal Color Language (UCL) which would include both the ISCC-NBS color naming system and the Munsell notation system. As they summarized it, the Universal Color Language is "a method or language of designating colors in simple, easily understood but accurately defined color designations in definite, correlated levels of accuracy of color designation" (p. A-18). The UCL describes six levels of increasing color specification accuracy. In each level, the complete color solid is divided into specified numbers of color blocks; the boundaries for each block are defined; and each level is related to all other levels. In level one, colors are specified in terms of 13 common color names. These 13 blocks are further subdivided into 29 blocks for level 2. Level 3 constitutes the ISCC-NBS method of designating colors, using a full set of 267 color names. Level 4 is divided into about 1,500 blocks, corresponding to the Munsell system. In level 5 the Munsell system is subdivided further by visual interpolation into even finer detail. Finally, in level 6, color is measured instrumentally and specified numerically by the CIE chromaticity coordinate system (to be discussed below). Thus, the UCL provides a way of systematically defining the appearance of colors. These specifications apply only to colors seen under average daylight or CIE source C.

Another system for specifying the color of an object or light is given in its most familiar form by the CIE chromaticity diagram. This system is based on the principle that three fixed colored lights (or "primaries") can be mixed to match any color (by means of a colorimeter or other instrument). The amounts of the three primaries needed to match the color are called tristimulus values. To avoid variations in matches between observers, the CIE specified a "Standard Observer", based upon the average values of a substantial number of observers (Wyszecki and Stiles, 1967). The color matching data of the CIE 1931 Standard Observer are considered representative of the normal human eye. The system is defined by three functions of wavelength, $\bar{x}$, $\bar{y}$, and $\bar{z}$ which represent the tristimulus values of the single wavelengths of the spectrum. (The primaries of the CIE system were chosen in such a way that these spectral tristimulus values are all-positive functions. Other choices of primaries can result in negative values.) Hurvich (1981, p.284) states: "To specify any illuminated object or surface colorimetrically we only require the object's or surface's spectral reflectance or transmittance and the spectral energy distribution (in relative terms) of the light source illuminating it. If the products of these two distribution curves at each wavelength are then multiplied by each of the standard observer spectral tristimulus values at each wavelength and the resultant values for all wavelenths added separately, we obtain the three numbers needed to specify the color. These three summed values are called the X, Y, and Z tristimulus values." The chromaticity coordinates x, y, and z are fractional equivalents of X, Y, and Z; i.e., $X = X/(X+Y+Z)$, etc. Because the CIE chromaticity coordinates are fractions which sum to unity, if two coordinate values are known, the third can be derived arithmetically. This principle has been used to develop the CIE chromaticity diagram, which is a two-dimensional diagram upon which the x and y coordinates are plotted (see figure 2). This diagram can be used to plot the chromaticity of any object, thus enabling its color to be specified without reference to a set of color chips or standard colors.

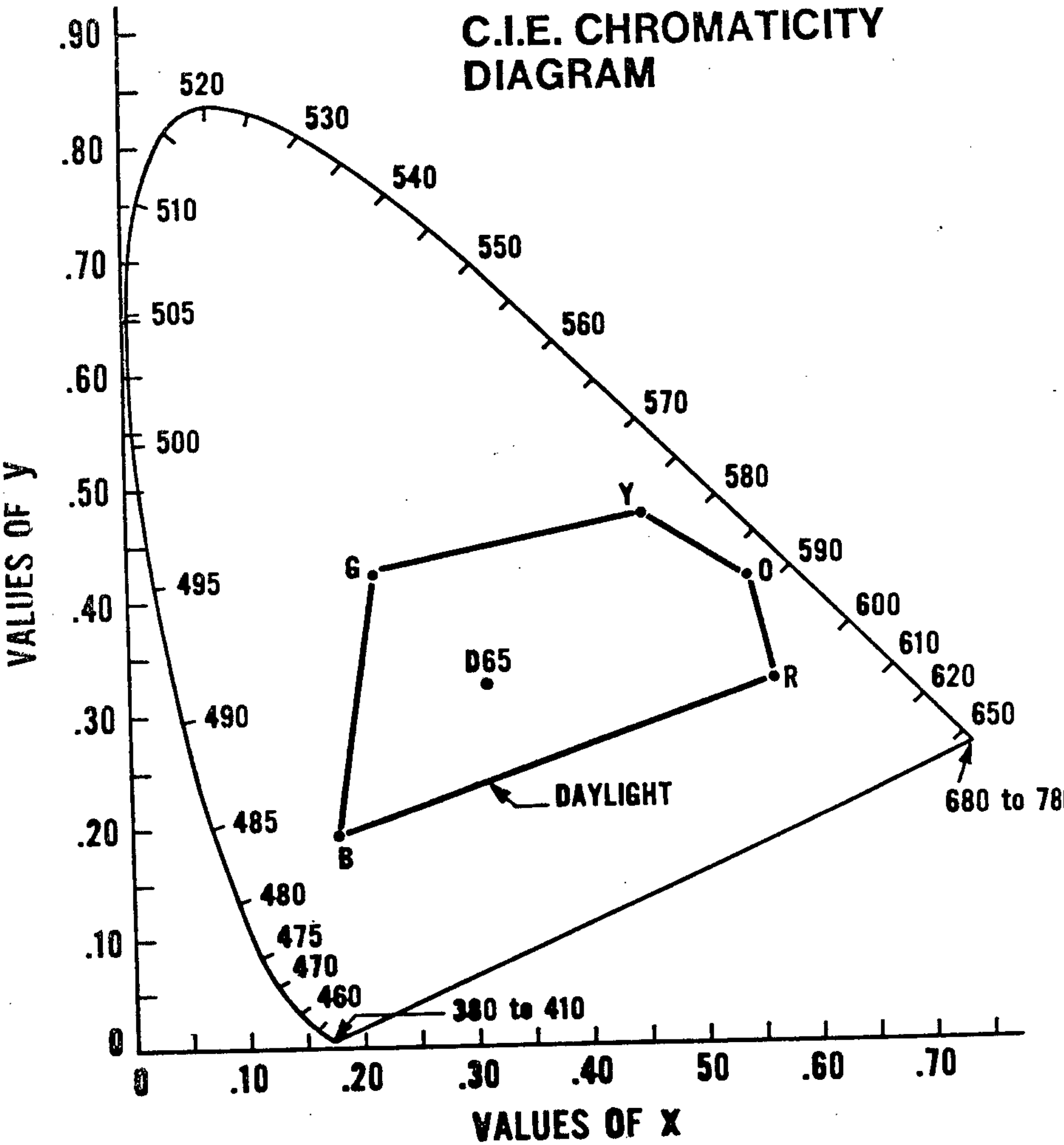

Figure 2. CIE chromaticity diagram containing the ANSI standard safety colors illuminated by daylight

In addition to the diagram itself, figure 2 plots the chromaticity values of the five basic ANSI standard safety colors for daylight illumination. Since the spectral reflectance of the object, and the relative energy distribution of the illuminant are the physical measures from which these coordinates are calculated, the accuracy of the coordinates is limited only by the accuracy of the physical measurements. Three-decimal-place accuracy of x and y is currently routine, and under special circumstances, the fourth place can be meaningful.

As an illustration of the three systems of color specifications discussed above, an example can be taken from the ANSI Z53.1-1979 Standard for Safety Colors (ANSI, 1979). This standard specifies Safety Red by the Munsell notation 7.5R 4.0/14. The 7.5R portion indicates the specific red hue; 4.0 the Munsell value (slightly below the medium lightness of value 5); and 14 the Munsell chroma, a quite high saturation. The standard also gives the equivalent CIE notation, which, to three figures, is x = 0.596, y = 0.327, and Y(%) = 12.00. The Y value, in the CIE system, is used to indicate the percentage luminous reflectance of the color sample. Finally, the descriptive ISCC-NBS color name is given by the standard as vivid red.

2.3.4 Color Coding Research

Color has been used extensively to code information (often when speed of communication is desirable). Christ (1975) analyzed data from 42 studies to assess the effect of color coding on visual performance. He found that when subjects were asked to identify two aspects of a visual display, such as color and shape, identification of color was more rapid and more accurate. Color was particularly superior as the number of stimuli increased, although it remained inferior to alphanumeric coding (perhaps the most familiar coding dimension). Christ (1975, p. 559-560) commented that "The most clear-cut finding is that if the color of a target is unique for that target, and if that color is known in advance, color aids both identification and searching." Only alphanumeric characters emerge as a superior coding dimension to color. Use of irrelevant colors, however, may interfere with the accuracy and speed of identifying or locating target attributes other than color. For the purposes of workplace signage, however, Christ's review underscores the ability of color to attract attention and encode relevant safety information in a rapid, accurate fashion. Color is particularly effective in a redundant cueing situation where the audience is knowledgeable about the color code--as is the case with signs in workplaces. Other individual studies have reinforced the finding that color is a particularly effective coding device. Thus, Saenz and Riche (1974), Shontz, Trumm, and Williams (1971), and Smith and Thomas (1964), found that color coding reduced search time and increased accuracy. This advantage is most clear-cut if the number of colors in the code does not exceed 8 to 10 (Cahill and Carter, 1976). Another study, by Easterby and Hakiel (1977), did not find clear evidence of the superiority of color coding. This study, which assessed symbol recognition, found that image content, perhaps comparable in information capacity to the alphanumeric characters discussed earlier, was more important than color coding in determining sign recognition. Yet, their subjects reported strong stereotypes for the use of color for fire, poison, and caustic hazard-warning symbols. Bresnahan and Bryk (1975) reported that industrial subjects associated red and yellow with a rated degree of hazard warning, thus suggesting that sign color can aid in communicating both the presence and level of hazard.

In summary, the preceding review of some color coding research underlines the importance of color coding in communicating information both rapidly and accurately. Unlike shape or size, color appears to be more effective, particularly if the code is limited to about 8 to 10 colors. Only alphanumeric characters (and perhaps pictorial symbols) are more effective coding dimensions than color--and this may be due to widespread familiarity with the characters. The use of color as a known, redundant cue appears to be highly effective, however, thus suggesting that the use of color-coded word/symbol signs is one of the best means of communicating safety information at least in the United States.

2.4 SIGN PERCEPTION

2.4.1 Background Research and Practice

Written signs are commonly used in industrial settings to alert workers to the presence of hazards and to provide safety information and instructions. They are particularly important in alerting the new worker who is unfamiliar with the job and industrial setting. These people are at higher risk during the initial months on the job (National Safety Council, 1979)

Recommendations about the effective use of signs assume that such messages are legible and visible in industrial settings. A number of factors may alter the visibility of such signs, however. These include low levels of illumination, poor contrast, poor color rendering, poor positioning, inadequate size, and poor durability. The effectiveness of signs can also be reduced by excessive visual clutter in the immediate neighborhood of the signs, including the presence of too many other signs. Even a single sign can be over-cluttered, with the inclusion of too many words or symbols.

2.4.2 Observed Sign Use

In a document prepared for NIOSH, Lerner and Collins (1980) reported site visits to six industrial plants to observe safety symbol, sign, and color use. Although they dealt mainly with sign use, they also documented different industrial uses of safety colors that are relevant to the present report. The six industrial sites studied represented a diverse range of industries, and included: the manufacture and assembly of truck engines, ceramic glass, aircraft, ships, as well as chemical and oil refining. These authors found that safety signs related more to potentially serious hazards such as explosion, fire, or the need for protective gear, with somewhat less reliance upon signs for frequently occurring but less serious hazards (such as slips, trips, and falls). With the exception of one site, the common practice was to use word signs, often quite lengthy signs. Of particular interest to the present report, was the widespread use of color coding to delineate areas for special protective gear or particular hazard. For example, yellow lines were commonly used to indicate a generally hazardous area; green to indicate the need to wear protective equipment or the presence of a safe walkway; orange for explosives; red for

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Safety Color Appearance Under Selected Light Sources

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NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

ABSTRACT

The present report provides data on the color appearance and physical measurements of 58 safety color samples viewed under each of seven light sources. Ten observers participated in an experiment which determined the accuracy with which different color samples could be identified under sources which varied in spectral composition. The seven light sources included incandescent, cool white fluorescent, clear mercury, metal halide, metal halide-high pressure sodium mix, high pressure sodium, and low pressure sodium. Color samples included ones for safety red, orange, yellow, green, blue, purple (magenta), brown, white, gray, and black of several different types including ordinary, fluorescent, retroreflective, and retroreflective fluorescent. Analysis of the data indicated that the standard ANSI (American National Standards Institute) samples were often not identified accurately under many of the sources studied, with particularly poor performance for the two sodium sources and clear mercury. Specifications are given for a new set of samples that were identified more accurately under all seven sources and which showed a greater gamut of coloration in a uniform color space for all sources. Chromaticity and luminance coordinates for all 58 color samples are presented for both CIE x,y,Y and CIE L*a*b* values. In addition, the psychophysical data are compared with the CIELAB data.

Keywords:

chromaticity, color, color appearance, energy-efficient lights, high-intensity discharge lights, illumination, light source, safety colors, vision.

FOREWORD

This report is one of a series documenting the results of NBS research in support of the Occupational Safety and Health Administration (OSHA) in fulfillment of an Interagency Agreement between NBS and OSHA.

The report summarizes research conducted in the period July 1983 - July 1986.

We wish to acknowledge with special thanks the interest, cooperation, and encouragement of the sponsor's Technical Project officers, Mr. Tom Seymour, Ms. Audrey Best, and Ms. JoAnne Slattery of the OSHA Office of Standards Development. We also wish to acknowledge with deep appreciation the efforts of Mr. Marvel Freund who was instrumental in designing, constructing, and building the illumination color lab, and those of Mr. Peter Spellerberg who wrote the computer programs for analyzing the psychophysical data.

DISCLAIMER

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EXECUTIVE SUMMARY

Several previous research studies (Jerome, 1977; Thornton, 1977, and Glass, Howett, Lister and Collins, 1983) have indicated that many of the standard safety colors (ANSI Z53, 1979) are not perceived accurately under some high intensity discharge (HID) sources.

The present study was an attempt to determine the extent to which the ANSI standard safety colors - red, orange, yellow, green, blue, purple, brown, white, gray, and black - are not accurately recognized under common HID sources, and to explore the effectiveness of a set of potentially better colors. A two-part experimental approach was used in the study.

First, psychophysical color data were obtained for a set of 58 color samples under each of seven light sources with 10 observers. The seven light sources included: low pressure sodium (LPS), high pressure sodium (HPS), clear mercury, metal halide, a high pressure sodium metal halide (HPSMH) mix, cool white fluorescent, and incandescent. Each observer provided data on color name (as related to safety alerting) and then gave judgments of primary hue, secondary hue, percentage of secondary hue, lightness, and saturation. In this way the appearance of each sample was specified in three dimensions for each source.

The second set of data was comprised of physical color measurements. In this portion of the experiment, the spectral reflectance of all 58 color samples was measured under incandescent light using a spectroradiometer. At the same time, the reflectance of a nearly perfect white diffuser was measured under all seven illuminants so that the spectral radiance factor could be calculated for all non-fluorescent samples for each source. The twenty-seven fluorescent samples were measured directly under each source, and spectral radiance factors calculated. The spectral radiance factor data were then converted into a uniform color space (CIELAB) so that the effects of varying sample and source could be easily assessed.

Results from the psychophysical investigation indicated that several of the ANSI standard colors, particularly red, orange, green, blue, and purple, were not accurately recognized under sources such as LPS, HPS and clear mercury. Examination of the physical gamut of coloration in a CIELAB a*b* space revealed reduced gamut - or diminished color differences - for these same sources relative to the incandescent source. Psychophysical results for the new samples indicated that two fluorescent samples, particularly red and orange, and several ordinary samples, including yellow, green and blue were more accurately recognized. In addition, the gamuts of coloration for these samples were always greater than for the ANSI samples regardless of the source.

The results suggest that effective safety alerting requires knowledge of the possible detrimental effects of the light source on the appearance of safety colors. Particularly for LPS, HPS and clear mercury, the use of supplementary good color rendering lighting or the use of the "best" colors should be considered.

Although further research is needed to evaluate the long-term stability of the fluorescent pigments, the improvement in performance relative to the current standard color samples suggests that the "best" colors deserve serious consideration as part of a more effective scheme of safety alerting.

1. Introduction

1.1 Overview

Previous research by Glass, Howett, Lister and Collins (1983) indicated that many of the standard safety colors (ANSI Z53, 1979) are not perceived accurately under some high intensity discharge (HID) light sources. Safety colors are used to encode different types of warning and safety messages. Current ANSI (American National Standards Institute) Z535 draft standards call for the following color use:

Red - Danger
Orange - Warning
Yellow - Caution
Green - Safety
Blue - Information
Black/White - Contrast
Gray, Brown, Purple - Reserved for later application.

Glass, et al, presented data indicating that selected fluorescent colors can be more effective than ordinary colors* under many common light sources and suggested several candidate safety colors. Their report did not provide any physical measurements of these new colors, however, and focused primarily on red samples (used to indicate dangerous conditions).

The present research was intended to extend the study by Glass, et al, and provide an in-depth analysis of the effects of variation in light source spectral composition on four different types of safety colors - ordinary, fluorescent, retroreflective, and retroreflective-fluorescent. The identifiability and physical color characteristics for 58 different color samples were studied for seven different light sources, including five HID sources. The first goal was to determine if there were a set of color samples that could be accurately identified for each safety color name - red, orange, yellow, green, blue, purple, brown, gray, black and white - under each of the seven sources. The second goal was to provide physical measures of chromaticity and luminance for each different color sample under all sources. The present study included a number of color samples used by Glass, et al, as well as some additional samples. It extended the number of light sources to include clear mercury, cool white fluorescent, and a mixture of high pressure sodium and metal halide, as well as the incandescent, metal halide, high pressure sodium, and low pressure sodium sources used in the earlier experiment.

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* In this report, an "ordinary"color sample is one which is neither fluorescent nor retroreflective.

1.2 Previous Research

Two recent studies also evaluated the effectiveness of safety colors under different light sources.

Jerome (1977) asked 20 observers to identify the primary color name of the ANSI standard safety colors under each of six sources (daylight fluorescent, incandescent, metal halide, deluxe mercury, clear mercury, and high pressure sodium). Jerome did not use low pressure sodium because pilot research had indicated that any differences between colors seen under this source were due primarily to brightness differences rather than color differences. As a result, he claimed that all colors would be confused under this source. In Jerome's study, the illuminance level was only 0.5 fc - the level specified by IES for emergency lighting. Each observer was shown the safety colors presented in a random sequence which included a single duplicate of each color as well as white, gray, and black. A total of 40 observations was made for each color under each source.

A two-step data analysis procedure was followed in which Jerome first tabulated the percentage of responses for each sample under each source. Then, he set criterion levels for performance: defining a slight confusion as 5-10 percent wrong answers; some confusion as 10-20 percent wrong answers; and a definite confusion as more than 20 percent wrong answers for a given color sample.

Jerome found no real confusions for the safety colors under daylight fluorescent light. For incandescent light, he found some confusion (10-20 percent errors) of green with blue, and purple with red. For metal halide he found some confusions between red and orange, blue and green, and gray and yellow. Under deluxe mercury, he found definite confusions between purple and red, yellow and white, gray and green, and black with both blue and purple. For clear mercury, Jerome found numerous definite confusions. These occurred between red, orange, and yellow, black and blue, and red with both purple and black, and green with white. In fact, purple was termed red more often than it was termed purple while black was termed red, blue or purple with equal frequency.

Under HPS Jerome also found many definite confusions. Again red, yellow, and orange were confused with each other, as were green, blue, and black. Orange, in fact was termed yellow 69 percent of the time. Red, purple, and orange were confused as were yellow and white. Gray was confused with both green and yellow. It should be noted that some of these confusions may have been due to the low illuminance provided (0.5 fc). Such a low level reduces the ability to make accurate color discriminations since it is below the level of photopic (color) vision. This may be one reason for the observed confusions between yellow and white, and green, blue and black.

Jerome concluded (1977, p.182) that "there are some light sources being used extensively under which the safety colors cannot be identified positively with any degree of certainty. Under these circumstances, if the safety colors are to perform their assigned function, supplementary lighting must be provided for the colors under which their identification can be determined without ambiguity."

Jerome also discussed the prediction of safety color appearance using the CIE Color Rendering Index (CRI). When the special indices of the CRI were computed for each color, it was found that the indices did not correlate well with the data. Jerome suggested (1977 p. 182) that "Apparently the answer is not how faithfully the colors are rendered, the attribute indicated by the Color Rendering Index, but how well the colors can be perceived as different from the other colors. That is, if the red can be identified as red and not some other color, even though it may differ greatly from its daylight appearance, it is performing its function as a safety color satisfactorily." Thus, the important attribute for safety colors is the difference in chromaticities between colors. Jerome calculated the gamut of coloration for the safety colors for the six sources studied on the CIE Uniform Color Space diagram (U*, V*). This analysis suggested "that if the adjacent colors are separated by at least 40 U*,V* units they can be distinguished at least 90 percent of the time" (1977, p. 182). The converse is not always true, since some colors separated by a smaller distance were identified correctly. Jerome concluded that "If the chromaticities of the safety colors illuminated by a particular source, plotted on the U*,V* diagram, are separated by less than 40 units confusion may exist and further investigations should be made to determine the extent of the problem and to determine what supplementary lighting may be necessary to eliminate it" (1977, p. 183).

In another effort, Thornton (1977) conducted a theoretical analysis designed to determine the chromaticities of a set of safety colors that should be more identifiable under common HID and tri-phosphor sources. He suggested that the problem was one of selecting object colors which would be identified correctly when presented by themselves. Thornton's solution to the problem of safety color identification was to redesign the colors themselves. When he calculated gamuts of coloration for the six standard ANSI colors under different illuminants, he found that the gamut of coloration for HPS and clear mercury was severely reduced, particularly for ANSI red.

Thornton suggested that altering the spectral reflectance of color samples to suppress blue-green and yellow reflectance could improve the recognizability under a number of sources. For lamps such as LPS and clear mercury, which have limited spectral power at wavelengths longer than about 570-590 nm and which cannot render reds properly, altering the spectral composition of the safety colors in these regions will have little effect. For these sources, the use of fluorescent materials appears to be the solution. Thornton presented suggested spectral reflectances for redesigned safety colors that would be more accurately identified under all sources.

Thornton also noted (1977, p. 95) that "auxiliary illumination on safety colors is simple in principle, and effective. For example, incandescent lamps may illuminate the safety colors, at added footcandle levels considerably below the footcandle levels of the offending main illuminant and good identifiability can be restored. However, in practice, auxiliary illumination is both expensive and unwieldy since many objects marked with safety colors are movable"...and could require complex, movable light sources.

In view of the preceding studies, the best solution to the problem of safety color identification appears to be the redesign of either the safety colors themselves or of the light sources. Although Worthey (1982, 1985) has pointed out that many conventional illuminants tend to decrease differences between red and green object colors, thus reinforcing the need to improve their color rendering properties, the present study was an attempt to determine if altering the spectral reflectance of particular object colors would improve their recognizability for sources already in common use. Several different types of safety colors and color pigments were thus studied under a variety of illuminants to provide baseline data on the effectiveness of "improved" safety colors.

2. Approach

2.1 Participants

Ten employees of the National Bureau of Standards, three females and seven males, participated in the experiment. Their age ranged from 20 to 53. All participants had normal (20/20) or corrected-to-normal visual acuity. They also had normal color vision, as verified by the A.O.H-R-R Pseudo-Isochromatic Plates.

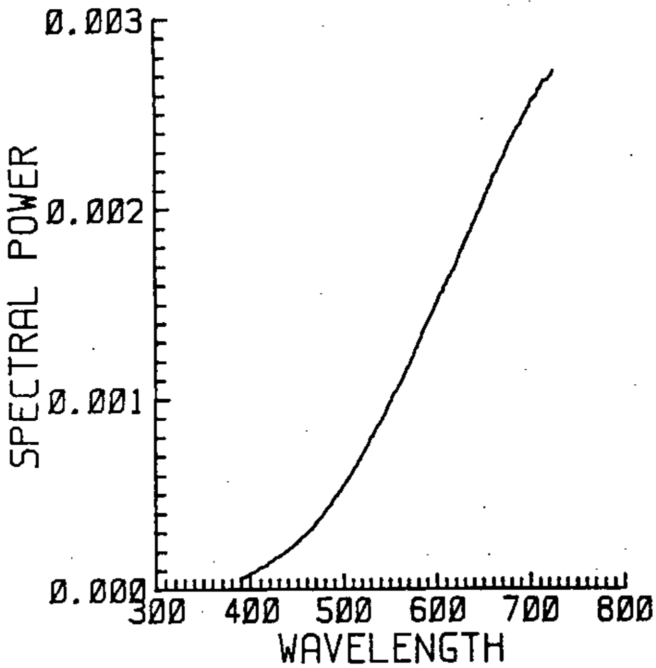
2.2 Apparatus

All experimental sessions were conducted in the NBS Illumination Color Laboratory which contains a smaller illumination chamber, 3.9 m by 2.5 m with a 2.4 m ceiling. For the experiment, gray canvas walls were used on three sides of the chamber with a movable black wall as the fourth side. The floors were of light grey speckled tile. The ceiling consisted of two layers of translucent plastic diffusers, above which were mounted seven different types of light sources. These sources represent commonly occurring energy-efficient or high color-rendering sources. Sources included low pressure sodium (LPS), high pressure sodium (HPS), metal halide (MH), clear mercury (MER), cool white fluorescent (CW), incandescent tungsten (TUN), as well as an equal luminance mixture of high pressure sodium and metal halide (HPSMH). The overall vertical luminance level at the sample location was between 79 and 550 cd/m^2. It was at the highest level only for LPS to maximize color recognition, if at all possible. Excluding LPS, the mean luminance was 107 cd/m^2. The overall illuminance was varied by means of mechanical shutters, so that problems of altering spectral power distribution by electronic dimming were avoided. Table 1 provides vertical luminance data measured for each source, while figure 1 presents measured spectral power distribution data for each of the seven sources used in the experiment.

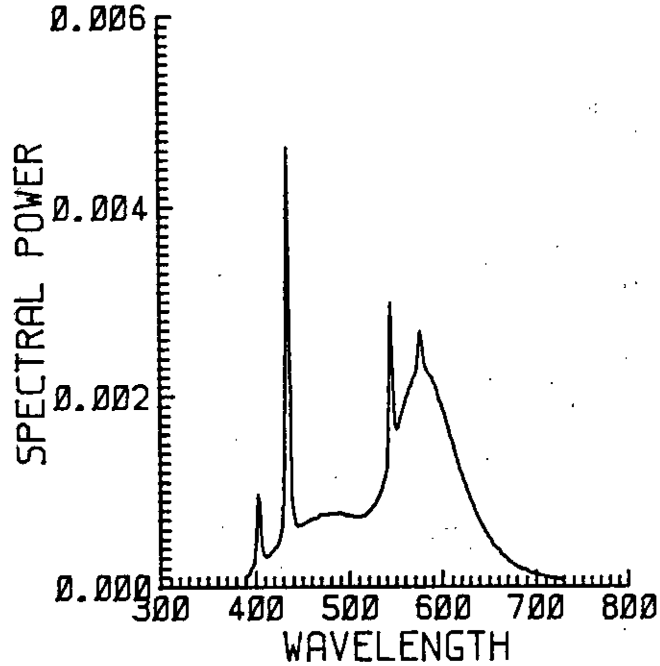
Four types of color samples were used in the experiment: ordinary surface (O) colors, fluorescent (F) colors, retroreflective (R) colors, and retroreflective fluorescent (RF) colors. (A fluorescent color is one which absorbs light at a given wavelength and reradiates it at a longer wavelength, while a retroreflective material is one which contains glass beads designed to reflect incident light back along the axis of incidence, thus increasing its night visibility.) All four types of materials are commonly used on safety and highway signs. The samples represented eleven nominal color name categories used in safety alerting. These included Red, Orange, Yellow, Green, Blue, Purple, Magenta, White, Grey, Brown, and Black. The color samples included the standard ANSI Z53 (1979) safety colors (ordinary colors), as well as several fluorescent and retroreflective colors that had been identified as effective in the previous experiment (Glass, et al, 1983).

Table 1. Vertical Luminance Data Reflected from a PTFE Standard Measured at the Sample Position During the Experiment.

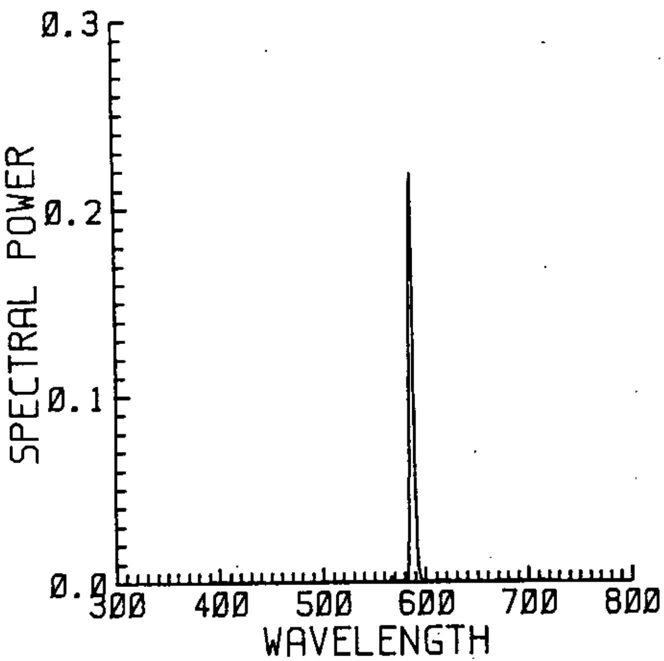
Incandescent light	78.8 cd/m^2
Cool White Fluorescent Light	113.0 cd/m^2
Clear Mercury	124.2 cd/m^2
Metal Halide	85.1 cd/m^2
High Pressure Sodium	108.0 cd/m^2
Low Pressure Sodium	550.0 cd/m^2
High Pressure Sodium/Metal Halide Mix	136.4 cd/m^2



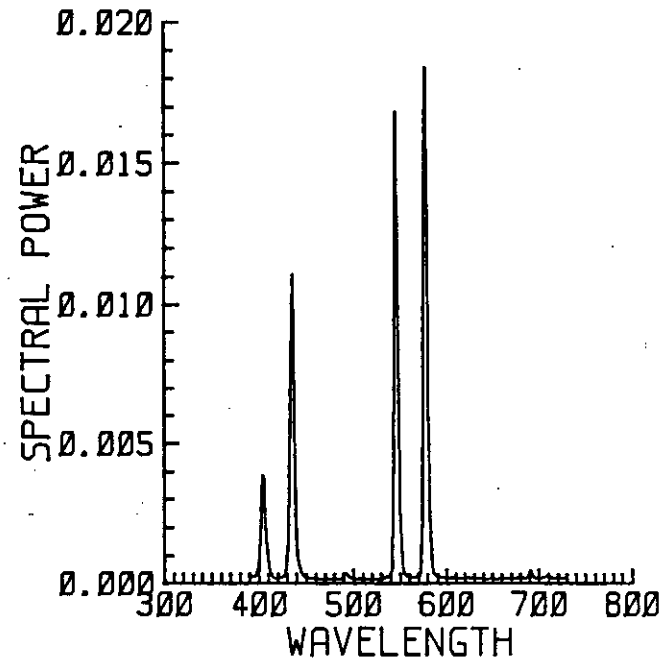
a. SPD of an Incandescent Illuminant



b. SPD of a Cool White Fluorescent Illuminant

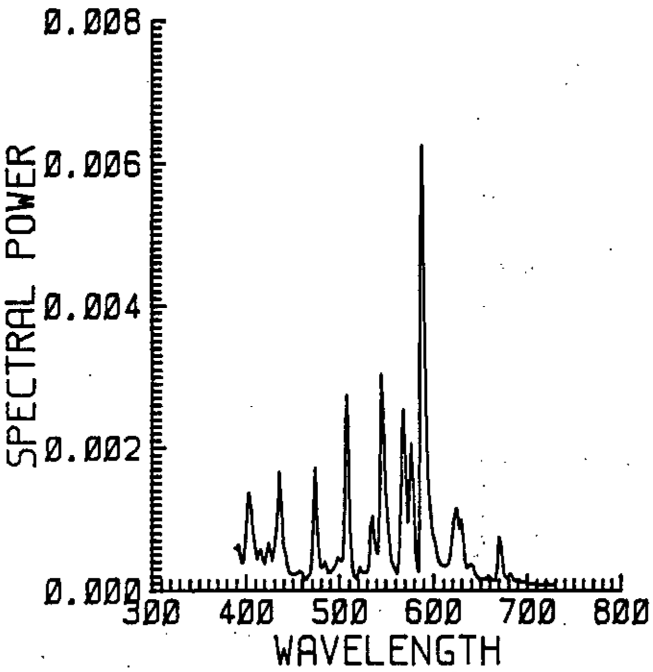


c. SPD of a Low Pressure Sodium Illuminant

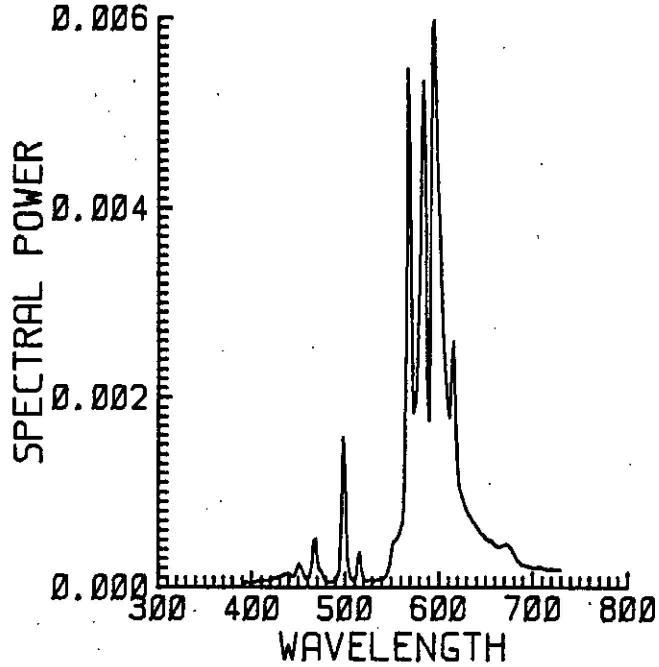


d. SPD of a Clear Mercury Illuminant

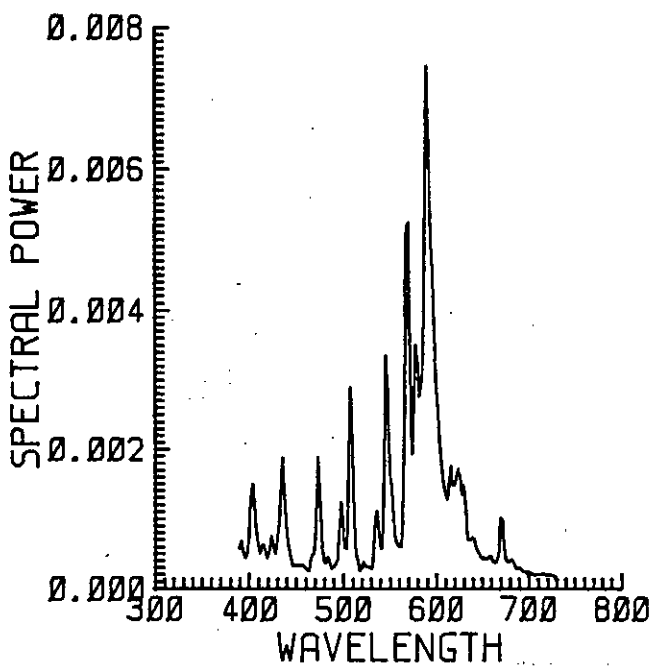
Figure 1. Spectral Power Distribution Data for Each Source Used in the Experiment.



e. SPD of a Metal Halide Illuminant



f. SPD of a High Pressure Illuminant



g. SPD of a Mixture of HPS and Metal Halide Illuminants

Figure 1 continued.

Although previous research by Glass, et al, had suggested that retroreflective samples were more identifiable than other samples, this finding was confounded with colorant type. Because it was not clear whether the effect was due to the colorant or the retroreflectance, in the present study several color samples were tested in both a retroreflective and an ordinary version. In particular, samples in the series 11 through 32 were available in both a retroreflective and non-retroreflective version. Strictly retroreflective samples were made in an ordinary form (e.g. 11 and 12), while retroreflective-fluorescent colors were produced in a fluorescent version only (e.g. 13 and 14). Samples 15-18 and 19-22 also represent variations of the same nominal color pigment. This approach allowed the effects of retroreflectance and fluorescence to be assessed for the same nominal color pigment.

Table 2 identifies the colors (using the manufacturer's color name), the sample type (O, F, R, or RF), and the sample number identifier. The eleven cases in which a pair of samples involved the same basic pigment in both a retroreflective and non-retroreflective version are listed at the bottom of table 2. In six of these pairs, the common pigment was ordinary, and in five pairs it was fluorescent. Although retroreflection was the principal difference between members of each pair, other confounding factors may have been present, including the thickness of the colorant layer and the nature of the substrate or backing material.

A total of 58 color samples was used in the experiment. They included the following nominal color names: eleven red, ten orange, eight yellow, ten green, six blue, five purple/magenta, two brown, four white, one gray and one black. Each sample was mounted in a plastic frame 12.7 cm by 17.8 cm.

2.3 Experimental Procedure

2.3.1 Spectroradiometric Measurement Procedure

Measurements of chromaticity and luminance were made for each color sample using a spectroradiometer. Illumination was provided by an incandescent source consisting of a small 12-volt spotlight with diffusing plastic mounted in front. The light was powered by a voltage regulated DC-source. It had a chromaticity of about x, 0.453, y = 0.419 or CIE 1960 u, 0.254, v = 0.353. Although the light was incident along the normal to the spot measured (about 7" away), the spectroradiometer was aimed at 45^o to the normal so that the spectral measurements had a 0^o-45^o geometry - thus excluding the specular component of reflectance for all practical purposes. For the ordinary samples, these measurements also provided spectral reflectance factor data.

Table 2. Identification of Samples Used in the Experiment for Each Nominal Color Name.

RED

Sample Number	Type
6	O (ANSI)
11	R
12	O
13	RF
14	F
33	R
34	R
45	F
57	F
58	F

ORANGE

Sample Number	Type
5	O (ANSI)
15	RF
16	F
17	R
18	O
35	R
42	RF
46	F
48	F
56	RF
47	F

YELLOW

Sample Number	Type
4	O (ANSI)
19	RF
20	F
21	R
22	O
36	R
37	R
49	F
50	F

GREEN

Sample Number	Type
3	O (ANSI)
23	RF
24	F
25	R
26	O
39	R
43	RF
51	F
55	R

BLUE

Sample Number	Type
2	O (ANSI)
27	R
28	O
40	R
52	F
54	R

PURPLE/MAGENTA

Sample Number	Type
1	O (ANSI)
29	RF
30	F
44	F
53	F

Table 2. Continued.

BROWN

Sample Number	Type
7	O (ANSI)
38	R

GRAY

Sample Number	Type
9	O (ANSI)

WHITE

Sample Number	Type
10	O (ANSI)
31	R
32	O
41	R

BLACK

Sample Number	Type
8	O (ANSI)

Measurements were also made under each source used in the experiment. All samples were first measured under TUN. For each illuminant, several measures of spectral reflectance were also taken for a PTFE (polytetrafluoroethylene or white diffusing) sample (Weidner and Hsia, 1981), yielding the data shown in figure 1. These measures provided baseline spectral power distribution data which allowed computation of the spectral radiance factor distribution for each sample.

The 27 fluorescent and retroreflective-fluorescent samples were also measured under all seven sources. These additional measurements were taken to determine the variation in spectral radiance factor as a function of light source due to fluorescing of the samples. All measurements were made with the sample mounted in the same position used for the observers. In this case, the light source was approximately 45^{o} from the normal to the sample, while the spectroradiometer was focused along the normal. Again the intent was to exclude specular reflections. Since some of the samples had glossy plastic covers, additional care was taken to exclude specular reflections for them.

2.3.2 Psychophysical Measurement Procedure

The psychophysical experimental sessions began with a 15 minute adaptation period to the light source during which the observer read material consisting of black print on a white surface. This adaptation time was sufficiently long to allow full light adaptation (about 1 to 2 minutes, according to Cornsweet, 1970). The overall light level maintained in the chamber was high enough (50-100 fc or 500-1000 lux) to permit each light source to reach maximum color rendering capabilities. Colored objects were removed from the chamber so as not to influence color judgements. The observer was also draped with a black cloth to remove supplemental color information and reflections from clothes. The observer was seated 1 m from the sample exposure area at a comfortable height.

During each experimental session only one light source was used. Observers saw all 58 color samples during a session. Some observers viewed the sample set twice, if they were not tired, and if the light source allowed easy identification of the colors. Because LPS caused so many problems in accurate color identification, all observers saw the full set of samples only once under this source in a session. The entire sample set was randomized for each exposure. The samples were exposed one at a time in the center of the black vertical wall at the observer's eye level (1.2 m). Samples were exposed briefly, but long enough to allow observers time to identify them.

In all, 140 experimental sessions were conducted, for a total of 8120 sample presentations. Every sample was viewed 20 times under each of the seven sources.

A set of five responses was selected for the observers to give for each sample under each light source. The first response was that of a simple, overall color name for the sample. This response was intended to determine the correspondence between the color name and the desired safety color for safety alerting purposes. To simplify the data analysis, observers were asked to restrict their choices to the following color names, or combinations thereof: Red, Yellow, Orange, Pink, Tan, Olive, Green, Blue, Purple, Gold, Magenta, Brown, White, Grey, and Black.

The other four responses, involving primary and secondary hue, lightness, and saturation, were chosen in an attempt to tie the observer's responses to existing color order systems, two in particular. The basic approach required of the observers for specifying color appearance paralleled the Munsell system, which categorizes colors in terms of hue, chroma (saturation), and value (lightness). Because hue was considered to be the most important variable in the present experiment, a fairly precise measure of hue was sought. Use of the number/letter notation for Munsell hue is abstract and difficult for inexperienced subjects to use. As a result, the observers were trained on the hue notation of the Swedish Natural Color System (NCS), which is tied direct to visual perception. The NCS characterizes colors in accordance with opponent colors theory using four fundamental hue perceptions - red, green, yellow and blue - and characterizes any hue as either being one of these, or as being some percentage of the way between two of the adjacent fundamental hues (Hård and Sivik, 1981).

Since lightness and saturation were considered to be less important than hue, and to avoid prolonged training on the numerical Munsell scales for these two dimensions, observers rated both variables on a three-point scale of High, Medium, and Low. It was expected that hue, saturation, and lightness would all vary for a given sample as a function of light source.

To summarize, the second response given by the observers was the identification of primary hue, while the third was the name and percentage of secondary hue. As an example of hue response, observers were told that one Orange sample might be a Red with 40 percent Yellow, while another might be a Yellow with 40 percent Red. The observer's fourth response was the lightness of the color in terms of High, Medium, or Low. As an example, they were told to consider brown as a dark orange. The fifth response was the saturation or vividness of a color, again in terms of High, Medium, or Low. Thus, an observer's response to a pink color might be: Pink, Red, 10% Blue, High Lightness, Low Saturation. Table 3 presents the instructions given to the observers.

Observers were first trained on the concepts used for the responses with the Munsell Book of Color - Glossy Finish (1976).

They were shown a page in the book and told that it presented a series of colors which were the same hue but which varied in lightness and saturation. They were shown how lightness decreases toward the bottom of the page, and how saturation increases toward the outer edge of the page. This procedure was repeated for each of the hue families. Once the experimenter was confident that an observer understood the concepts of hue, lightness, and saturation, he or she was given a practice session in the illumination chamber. For this session a set of colors used in the previous experiment by Glass, et al (1983) was used under incandescent (TUN) light. Observers went through the response procedure, with the experimenter providing feedback if the observer expressed difficulties or if the response seemed inappropriate. Once the experimenter believed that the observer understood the procedure, the experimental sessions were begun. A source with at least reasonably good color rendering was chosen for the first session so that the experimenter could be sure that the observer's responses were appropriate. As Hard and Sivik (1981) reported, observers were able to make consistent, reliable judgements of color appearance with only 15-30 minutes of training.

Table 3. Instructions to Observers for

Experiment on Safety Color Appearance

We are conducting an experiment on the appearance of colors under different types of light sources. The colors have been carefully chosen to be easily recognized under daylight illumination. Under different light sources, however, they may not be recognized as easily. As a result, we are conducting an experiment to determine what the colors look like under a variety of commonly used light sources.

In this experiment we will ask for five different types of information from you about the appearance of each color.

The first is your very first reaction to the color--its color name. This is your initial reaction to the color. We want you to tell us what color you see. If possible, please restrict your choices to the following color names, or combinations thereof:

Red, Yellow, Orange, Pink, Tan, Olive, Green, Blue, Purple,

Gold, Magenta, Brown, White, Gray, and Black

Secondly, we want to know what the underlying hue is. For this judgement, you may think of a color circle with RED at the top, YELLOW at the right, GREEN at the bottom, and BLUE at the left.

RED

BLUE YELLOW

GREEN

Third, we want to know what the secondary hue is, if any. Because any color may be formed by a combination of two of these hues, we want you to give us the primary hue, followed by the percentage, if any, of the secondary hue. For example, you may think of orange as a RED with 40% YELLOW; or a brown, as a YELLOW with 30% RED and also low lightness and saturation.

The percentage of secondary color may be any number up to 50%. For example, you may see a blue green that is mostly blue, but partly green. You would term that "BLUE", 20% (or some such percentage) green. A fifty percent mixture would mean that the color was equally blue and green. We will provide you with some examples under good light to demonstrate what we mean.

The fourth type of information concerns the lightness of the color. Is it light or dark? Light means that there is a great deal of white in the color; dark means a great deal of black. Again, we will show you an example.

The fifth type of information concerns the saturation or vividness of the color. This relates to the amount of chromatic quality in the color--or the strength of the color. It is a measure of how much a color differs from a gray of the same lightness. A color can be saturated and either light or dark.

Please note that we are considering that white, gray, and black have no saturation. Also by definition white is high in lightness, and black is low.

To explain color name, lightness, and saturation further, we will show you examples from the MUNSELL BOOK OF COLORS.

Each page of this book presents a series of colors which vary in lightness and saturation for one color (or hue, in the Munsell system). As you go down the page for the color, the lightness decreases. Thus, colors higher on the page are lighter; colors lower on the page are darker.

Variations in saturation are shown in the horizontal direction. As you go out from the spine of the book towards the edge, the saturation increases. Thus, colors near the spine are dull or low in saturation; colors near the edge are vivid or high in saturation. Colors along a row all have the same lightness, while colors in a column all have the same saturation.

We would like you to retain the idea of both lightness and saturation as dimensions which additionally define the appearance of a color. To do this please indicate the amount of lightness by saying HIGH, MEDIUM, or LOW LIGHTNESS. Similarly, please indicate the amount of saturation next by saying HIGH, MEDIUM, or LOW SATURATION.

Thus for this experiment, we ask you to:

Give the color name;

Give the primary hue, in terms of RED, YELLOW, GREEN, or BLUE.

Give the secondary hue; and the percentage of secondary hue, if any, up to 50%;

Give the lightness of the hue, using High, Medium, or Low;

Give the saturation of the hue, using High, Medium, or Low;

If you get confused, the experimenter will remind you which variables you have mentioned.

3. Psychophysical Results

3.1 General Findings

3.1.1 Tabulation Procedures

Each observer's responses were recorded for each color chip as they were uttered. The color name was recorded first, followed by the primary hue name. The secondary hue name, and percentage of secondary hue, if any, was given next. The observer then gave the lightness and saturation judgments for the sample. For about half the observers, these data were recorded by hand and later transcribed into a computerized database management program. For the other observers, the data were recorded directly by a computer into a database management program.

Data recorded included sample number, observer identifier, source, date, color name, primary hue, secondary hue, percent secondary hue, lightness, and saturation. The database management program was then used to sort the data by observer and light source for each sample number. The summary tabulations enabled the data for each color sample to be examined for a given source so that anomalies such as repeated entries could be detected readily..

Because of the amount of raw data, the database was further organized. In this step, data for selected samples were compiled and combined. The first step was to convert color names to one of the categories initially given to the observer to use. The following categories were selected based on the originally suggested responses and the actual names given by the observers: Red, Red-Orange, Orange-Red, Pink, Orange, Gold, Yellow, Yellow Green, Tan, Olive, Green, Blue-Green, Blue, Purple, Magenta, Brown, Gray, Black, and White. This categorization was intended to identify those cases where a color name was used that was not a valid safety color. The following rules were used for this categorization:

a) Any modifier referring to lightness or saturation was dropped, e.g. "Light", "Dark", "Pale", "Dull", "Bright", "Fluorescent", "Brick", etc., because lightness judgments had been obtained separately.

b) Combined colors were categorized with the non-safety color part of the pair; e.g. Olive-Green as Olive; or Yellow-Tan as Tan. Red-Brown was tabulated as Brown since the sample was obviously not seen as safety Red.

c) Red-purple and Purple-pink were categorized as Magenta.

d) Maroon (given by only 2 observers) was categorized as brown rather than purple or magenta, since it was generally reported to have a red primary hue and a yellow secondary with low lightness and saturation. While purple might appear to be an appropriate name, no nominal purple was ever termed maroon under any source. Rather, use of maroon was confined to some nominally red samples under certain sources, such as mercury.

e) Where observers combined color name categories, these were generally retained. Combined categories included red-orange, orange-red, yellow-green, and blue-green. Yellow-green and blue-green combined all responses that were either green and yellow, or blue and green, regardless of order. Red-Orange and Orange-Red were treated as separate categories because of the importance of both Red and Orange in signaling the presence of a hazard.

A series of 58 detailed tables (one for each sample) was generated based on the categorization described above. Each table contains five tabulations: Color Name, Lightness, Saturation, Primary Hue, and Secondary Hue for each individual color sample. In the first block, the 19 possible Color Names are listed along with the frequency of occurrence of that name for each source. Twenty responses for Color Name (two from each of 10 observers) were obtained for each source. The next block presents the frequency with which a sample was categorized into one of the three lightness levels. Similar tabulations were made in the third block for each of the three possible saturation levels. In the latter case, responses may not sum to 20, since some colors were seen as gray, white or black under selected sources. Gray, white, and black have no saturation, by definition. (Some grays and whites were seen as highly saturated yellows under LPS, however.)

The fourth tabulation was that of primary hue. This block of the table lists the frequency that each of the four primary hues (Red, Blue, Green, and Yellow) was given for each sample under each source. In addition, the block lists the mean percentage of hue assigned to the primary hue component. Two steps were taken to obtain the percentage of primary hue. First, the individual percentage of primary hue was obtained by subtracting the percentage of secondary hue associated with that primary hue from 1.0 (meaning 100%) for each hue given by a observer. Thus, if a observer termed a particular sample as Red only, its primary hue would be recorded as red and the percentage as 100. If a secondary hue were given, such as blue-10%, the percent of red would be calculated to be 90%. All calculated percentages for each hue name were then summed and divided by the number of responses for that hue name to obtain a mean percent of primary hue. Note that the total frequency for the primary hue was sometimes less than 20 in cases where a sample was seen as neutral (white, gray, or black).

The fifth tabulation provides similar information for secondary hue. The same procedure for calculating mean percentage was followed, except that the initial percentages did not have to be calculated. Because there were numerous cases in which secondary hue names were not given, fewer than 20 responses occurred for many sample/source combinations. This means that in a number of cases the mean percentage of primary hue and of secondary hue do not sum to 100.

Because of the sheer volume of data, the 58 detailed tables are presented and discussed in Appendix A.

3.1.2 Overview of the Results

Table 4 compares the data on dominant color name for the ANSI standard samples (indicated by an asterisk) with the data for several new samples. The new samples are those that emerged as "Best" in terms of percentage of accurate color recognition. The table tabulates the percentage of times the sample was given the dominant color name as appropriate for the nominal color categories shown in Table 1. In cases where no color name emerged as dominant, secondary color names are also given.

Inspection of Table 4 reveals striking effects due to the light source. While findings for each color sample are discussed in detail in the appendix, inspection of table 4 indicates that the ANSI red sample was rarely termed red by all observers under every source. Performance was particularly poor under HPS, LPS and MER. Performance was also poor for the ANSI Orange under these particular sources. For both red and orange, performance was much better for the new fluorescent samples (57 and 48), although it still remained rather poor under LPS. Light source had less apparent effect on the appearance of yellow, although both MER and MH diminished performance for the ANSI yellow sample. Light source, however, had a notable effect on the green samples, with neither the ANSI nor the "best" sample being seen as green under LPS. Both these samples tended to be called blue green or green under all sources except LPS. While almost all blue samples were named correctly under most sources, only one sample (the "best" one, sample 28) was also named correctly under LPS. Purple, white and brown also were not named accurately under LPS.

For a detailed discussion of the results for each sample, please see Appendix A.

Table 4. Percentage of Times Sample Given Dominant Color Name Under Each Source.

Sample	Name	CW	HPS	Mix	LPS	MER	MH	TUN
			Nominal Red					
6	Red	55						60
	Orange		75	45				
	Olive				40			
	Brown					100		
	Red-orange						45	
57	Red	85	85	75	40	90	95	85
	Brown				35			
			Nominal Orange					
5	Orange	65		50			55	85
	Yellow		65		100	60		
	Gold			25				
48	Orange	90	100	90	100	100	100	95
			Nominal Yellow					
4	Yellow	75	95	85	100	40	80	85
	Yellow Green					50		
22	Yellow	80	95	90	100	65	85	85
			Nominal Green					
3	Blue-green	45	50	45		85	40	35
	Green	55	40	50			60	65
	Gray				65			
26	Blue-green	50	75	70			60	45
	Green	50	10	25		85	35	55
	Gray				85			
			Nominal Blue					
2	Blue	100	100	100		40	100	100
	Purple					60		
	Gray				60			
28	Blue	100	100	100	70	95	100	100

Table 4 Continued.

Sample	Name	CW	HPS	Mix	LPS	MER	MH	TUN
				Nominal Purple				
1	Purple	100	95	100		100	100	75
	Gray				35			
				Nominal Brown				
7	Brown	100	55	75		55	90	95
	Olive		35		30	35		
	Tan				30			
				Nominal White				
10	White	100	100	100		95	95	100
	Yellow				100			
				Nominal Gray				
9	Gray	95	95	95		100	100	95
	Olive				45			
				Nominal Black				
8	Black	100	100	90	80	90	100	100

3.2 Statistical Comparison of Samples

Several color samples were available in different formulations of the same nominal pigment; such as ordinary and fluorescent, retroreflective and retroreflective-fluorescent, etc. The performance for these different sample types was compared, to determine if adding retroreflectivity to a sample altered its appearance under different sources.

Chi square comparisons of the results given in Table 5a indicated few significant differences between pairs of samples containing retroreflective materials. This analysis compared the frequency of responses for the nominally correct dominant color name for the two samples for each light source. The only significant differences emerged for samples 25 and 26 (retroreflective vs. ordinary); samples 15 and 16 (retroreflective-fluorescent vs. fluorescent); and samples 19 and 20 (retroreflective-fluorescent vs. fluorescent). In these cases, performance was superior for the non-retroreflective samples. Consequently, one cannot draw any conclusions about the benefits of retroreflectance in improving safety color appearance under LPS or any other source.

Further chi square comparisons were made between the original ANSI standard samples and new versions of the samples to determine if the new samples were identified significantly more correctly under all light sources. Table 5b presents a summary of these comparisons. Inspection of table 5b reveals that two red samples, 57 and 58; three orange samples, 16, 48, and 42; two green samples, 55 and 39; and one blue sample, 28 performed better than the appropriate ANSI standard. All yellow samples performed well under all sources so that no significant differences in performance were observed. On the other hand, no purple, white or brown sample did better than the ANSI standard - with none of these samples, regardless of composition, being correctly identified under LPS.

Additional comparisons were made between several "new" samples for a given nominal color name relative to each other. These comparisons involved samples 21 vs. 22 and 20 vs. 36 for yellow; samples 57 vs. 58 for red; 55 vs. 39 for green; and 16 vs. 48 and 15 vs. 42 for orange. Of all these comparisons only that of sample 16 vs. 48 was significant ($p<.025$). This difference is attributable to the better performance for 48 under LPS, where it was correctly identified by 20 observers (compared with one correct response to sample 16).

The frequency of errors in the observations was examined for samples, sources and observers for the ten ANSI standard samples and the six best samples. This analysis examined the frequency of errors in color name - or those times in which a sample was given a color name that was different from either the dominant color name or the correct color name.

Table 5. Statistical Comparisons Between Sample Types Studied.

5a. Comparison of Nominal Pigment Types

Nominal Color	Comparison	Sample Type 1st	Sample Type 2nd	Significance
Red	11 vs. 12	R	O	NS
Red-orange	13 vs. 14	RF	F	NS
Orange	17 vs. 18	R	O	NS
Orange	15 vs. 16	RF	F	Sig
Yellow	21 vs. 22	R	O	NS
Yellow	19 vs. 20	RF	F	Sig
Green	25 vs. 26	R	F	Sig
Green-yellow	23 vs. 24	RF	F	NS
Blue	27 vs. 28	R	O	NS
Magenta	29 vs. 30	R	RF	NS
White	31 vs. 32	R	O	NS

5b. Comparison of ANSI Standard with New Samples

Nominal Color	Comparison	New Sample Type	Significance
Red	6 vs. 58	F	p<.001
	6 vs. 57	F	p<.001
	6 vs. 33	R	p<.01
Orange	5 vs. 16	F	p<.05
	5 vs. 48	F	p<.001
	5 vs. 42	F	p<.001
Yellow	4 vs. 36	R	NS
	4 vs. 20	F	NS
	4 vs. 21	O	NS
	4 vs. 22	R	NS
Green	3 vs. 55	R	p<.05
	3 vs. 39	R	p<.01
	3 vs. 24	F	NS
	3 vs. 23	RF	NS
Blue	2 vs. 28	O	p<.05
	2 vs. 27	R	NS
	2 vs. 52	F	NS
Purple/magenta	1 vs. 44	F	NS
	1 vs. 53	F	NS
White	10 vs. 32	O	NS
Brown	7 vs. 38	R	NS

Table 6 presents a tabulation of errors for each sample, source and observer. For each sample a total of 140 observations were made, as shown in Table 6a. The mean frequency of errors for all sources was low (20.9 or about 15%), with a range of 2 to 50. Of interest are the five sample types for which both an ANSI standard and a new sample exist - red, orange, yellow, green and blue. The mean number of errors for the ANSI set was 28.6 while the mean number for the new set was 14.0 - a noticeable reduction in the frequency of errors.

The error rate also varied as a function of source and observer. Table 6b tabulates observer errors for each source, along with observer and source statistics. The mean number of errors per observer out of the 224 possible observations is quite small, between 3.00 and 8.14 (about 2 to 4 percent). Two observers, 1 and 6, had slightly higher error rates, however. They were the oldest observers in the study and may have had some yellowing of the lens which affected their color judgments. Similarly, errors for sources ranged from a low of 2.3 for TUN to 9.1 for LPS (or 0.7 to 2.8 percent). Thus the fewest number of errors occurred for the source with the highest color rendering index (CRI), while the greatest number of errors occurred for the source with the lowest CRI, as might have been expected.

3.3 Selection of Improved Safety Colors

Based on the preceding comparisons of performance, several "new" color samples can be considered as candidates for standard colors which are more accurately identified under the seven sources studied.

Two approaches were followed for selecting new candidate safety colors. The first was the statistical comparisons discussed above. The second was a rank-ordering using the following criteria: 1) high frequency of desired color name; 2) high frequency and high percentage of desired primary hue; 3) low percentage of secondary hue (except for orange and purple where equal percentages of red and yellow or red and blue as primary and secondary hues were desirable); 4) appropriate lightness (high for yellow but low for blue); and 5) high to medium saturation. When several samples appeared to meet all criteria equally, they were given the same rank. This situation occurred frequently for the blue samples where there was little difference in performance among several samples. Where a sample could not be ranked, such as white or purple under LPS, it was given an X. Table 1B of Appendix B presents only the sample numbers receiving ranks 1-3 for each safety color for all sources. In this way, one can examine Table 1B and determine which samples were ranked 1, 2, or 3 most frequently for all sources.

Based on the statistical comparisons and rank ordering, the best

Table 6. Frequency of Color Name Errors for Each Sample, Source, and Observer.

Table a. Errors for Specific Color Samples - 140 Observations

	ANSI Purple	ANSI Blue	New Blue	ANSI Green	New Green	Yellow Green	ANSI Yellow	New Yellow
Sample	1	2	28	3	26	23	4	22
Error	13	16	7	11	9	38	27	20

	ANSI Orange	New Orange	ANSI Red	New Red	ANSI Brown	ANSI Black	ANSI Grey	ANSI White
Sample	5	48	6	57	7	8	9	10
Error	39	5	50	29	34	8	13	2
Mean Errors	20.92							

Table b. Frequency of Errors for Observers and Sources

Observer	CWF	HPS	LPS	MER	MH	MIX	TUN	Observer Mean	%	Std. Dev.
1	1	1	15	9	5	5	4	5.7	2.5	4.6
2	2	1	6	6	4	7	1	3.9	1.7	2.4
3	6	4	5	6	5	3	2	4.4	1.9	1.4
4	3	4	7	5	3	5	1	4.0	1.7	1.8
5	7	7	17	9	4	5	8	8.1	3.6	3.9
6	5	1	6	8	5	3	1	4.1	1.8	2.4
7	7	4	5	4	2	7	1	4.3	1.9	2.1
8	2	1	10	2	0	2	4	3.0	1.3	3.1
9	3	3	9	4	4	3	0	3.7	1.6	2.5
10	1	6	11	4	3	4	1	4.3	1.9	3.2
Source Mean	3.70	3.20	9.10	5.70	3.50	4.40	2.30			
Percent	1.1	1	2.8	1.8	1.1	1.4	0.7			
St. Dev.	2.24	2.09	3.99	2.24	1.50	1.62	2.28			

choice for a safety red is sample 57 followed by 58. Both samples were significantly different from the ANSI standard (6); and were identified correctly under all light sources including LPS (this latter at a much lower rate). Although sample 33 was identified correctly under TUN, CW, HPS, HPSMH, and MH, its poor performances for both MER and LPS should eliminate it from consideration.

For Orange, performance was significantly better for 16, 48, 42, and 15 than for the ANSI standard (5), with a significant difference arising between 16 and 48. Sample 48 appears to be the best choice because of its good performance under LPS, as well as the other sources, although 15 is a close second.

For Yellow, 22 appears to be the best choice, although 4 is a close second. Sample 4, however, was not seen as yellow under MER as frequently as sample 22. No statistically significant differences in performance emerged for these two color samples, however.

For Green, the best choice for a blue green appears to be sample 26, which was consistently identified as green or blue green under all sources except LPS. Sample 23 is a good yellow green, although its performance was not as good under MER as that of sample 26.

For Blue, the best choice is sample 28 because of its good performance under all sources including LPS.

For Purple, only sample 1 was identified as purple - the others were considered to be pink. No sample, however, was identified as either purple or pink under LPS, meaning that any color coding using purple under this source would be ineffective. Sample 1 is quite effective under the other sources, however.

For Brown, there was very little difference in performance between sample 7 and sample 38, although sample 38 was identified accurately somewhat more frequently than 7. Only 2 observers identified either sample as brown under LPS. As a result, the ANSI standard appears acceptable.

For White, performance for sample 10 was as good as for 32 under all sources, except LPS where neither was identified as white. Sample 10, the ANSI standard, thus appears to be a reasonable candidate for Safety White. Similarly, sample 9, ANSI gray, had good performance under all sources except under LPS where it was generally identified as olive or yellow. Sample 8, ANSI black, was identified accurately under all sources. Thus the ANSI Gray and ANSI Black are successful safety colors (except under LPS). While this approach tended to weight all light sources equally, thus giving LPS as much importance as better color rendering sources, the sample selection would not be markedly altered if results for LPS were dropped from consideration.

Samples with the best performance for red, orange, and green tended to be the fluorescent ones. Thus the red 57 and 58, the orange 48, and the green 23, were typically ranked 1 or 2 for all sources. Yet, ordinary surface colors were effective for yellow (22), blue green (26), and blue (28). In the present study, there was no tendency for retroreflective samples to perform better than their counterpart ordinary or fluorescent samples.

Data from the present experiment are consistent with those of Glass, et al, (1983) who had also found samples 57 and 58 to be some of the best reds tested. Although they had also found samples 54, 55, and 56 to be the best blue, green, and orange samples respectively, performance, while good for these samples in the present study, was even better for several new samples. Thus, the blue sample 28, the green samples 23 and 26, and the orange sample 48 (which were not studied by Glass, et al) were the most successful examples of safety blue, green, and orange respectively.

4. SPECTRORADIOMETRIC RESULTS

4.1 Chromaticity and Luminance Data

As described in 2.3.1, spectroradiometric data were obtained for each sample. First, all 58 samples and the PTFE standard were measured under tungsten. Then the PTFE standard and the 27 fluorescent samples were measured under the remaining six sources. The resulting spectral reflectance factor distributions for each sample under each source were converted to data readable by a personal computer (PC) which converted them to chromaticity and luminance values in both the CIE x,y and CIELAB color spaces.

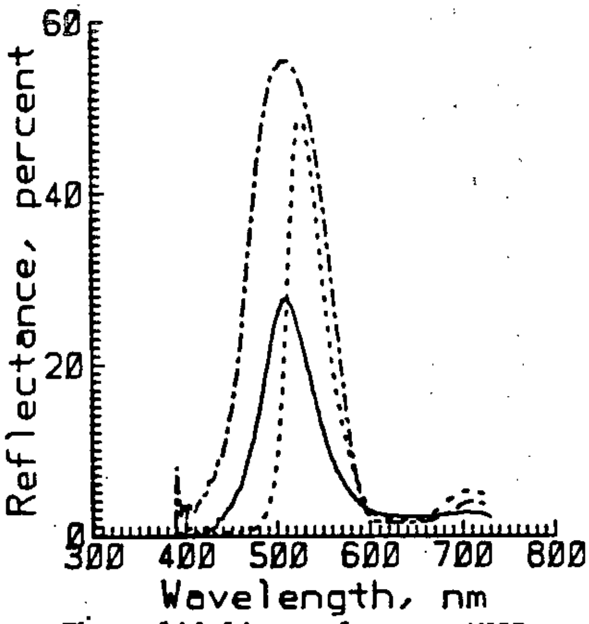
Figures 2 and 3 present spectral reflectance factor distributions for the ANSI standard and "best" samples under a tungsten illuminant, and then under a mercury illuminant. The mercury illuminant was chosen to demonstrate the effects of sample fluorescence. It should be noted that fluorescence will vary as a function of the illuminant's spectral power distribution, so that these graphs are not representative of all seven sources.

A series of additional calculations was performed for the ordinary samples, including the ANSI standard samples (1-10). Since these samples were actually measured only under the incandescent source, spectral reflectance factors were calculated for the six additional sources used in the experiment as well as for the standard CIE illuminants - A, B, C, and D-65. CIE Y,x,y and L*a*b* chromaticity and luminance values derived from these data are presented in table 2B of Appendix B. Table 2B also presents similar data for the "Best" samples. For fluorescent samples, chromaticity and luminance values are given only for the source under which the sample was actually measured.

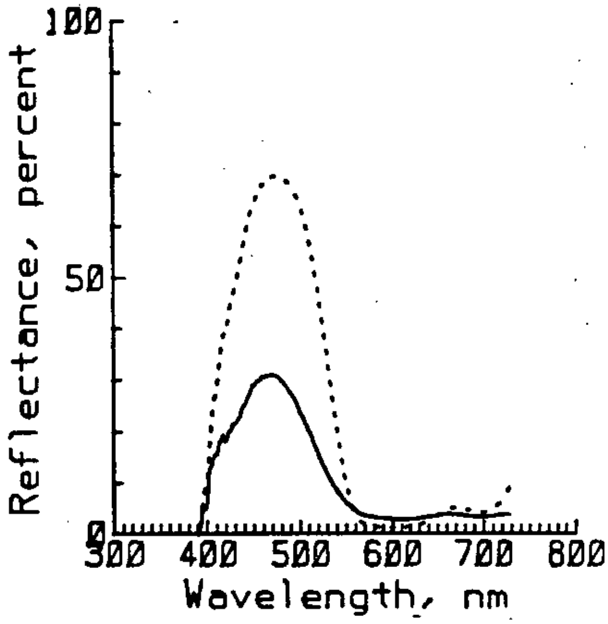
4.2 Uniform Color Space

Once spectroradiometric measures of each sample were obtained, they were converted into a uniform color space for easier comparison. A uniform color space, CIELAB, was used to compare different samples under different illuminants because the spacing between samples in this space corresponds more closely to the human visual response than it does in the original CIE x,y space.

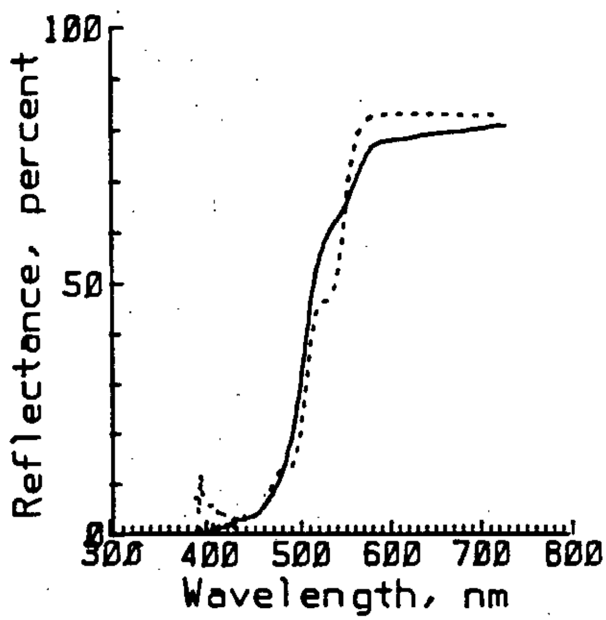
The CIE (1978) defined two uniform color spaces for use with color difference formulae. The first space defined by the CIE, CIELUV, uses a modified version of the CIE 1964 color difference formula. CIELUV is particularly useful for assessing the effects of mixing colored lights additively. The other space, CIELAB, is a cube root version of the formula developed originally by Adams and Nickerson. The CIE stated (1978, p.9) that: "The cube-root version of the Adams-Nickerson color-difference formula is based on a uniform color space, which for constant psychometric lightness (L*) incorporates an (a*b*) diagram in which straight



The solid line refers to ANSI Green under TUN; the dashed line refers to the "best" Yellow green (#23); and the dash-dot line refers to the "Best" Blue-green (#26), both under TUN

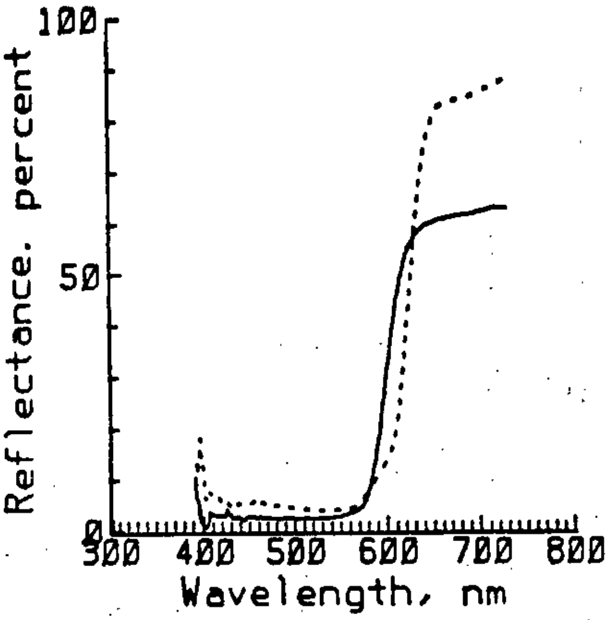


The solid line refers to ANSI Blue under TUN; the dashed line refers to the "Best" blue (#28) under TUN.

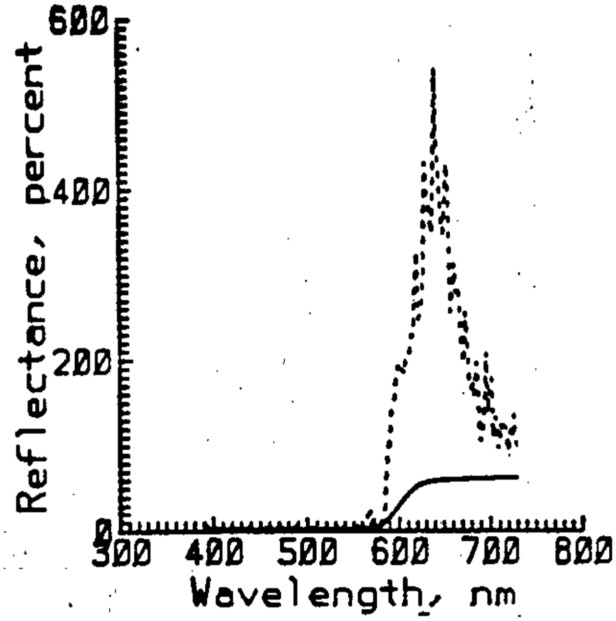


The solid line refers to ANSI Yellow under TUN; the dashed line refers to the "Best" yellow (#22) under TUN.

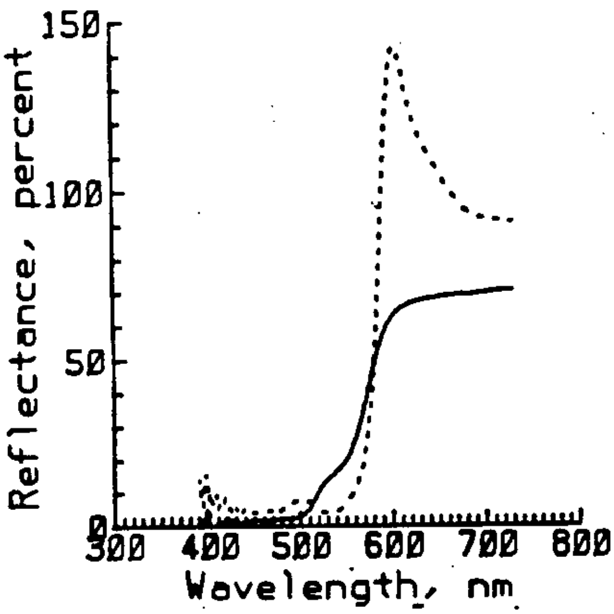
Figure 2. Comparison of spectral reflectance factors of ANSI standard green, blue, and yellow samples with "best" samples under tungsten illumination.



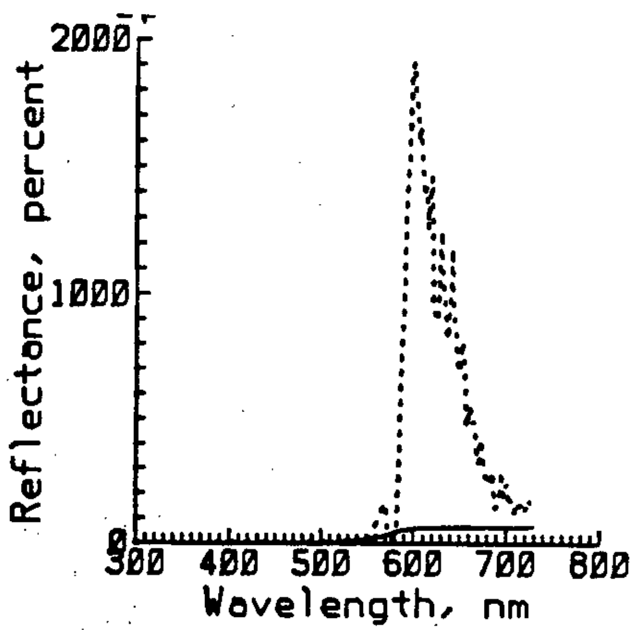
The solid line refers to ANSI Red under TUN; the dashed line refers to the "Best" Red (#57) under TUN.



The solid line refers to ANSI Red under MER; the dashed line refers to the "Best" Red (#57) under MER.



The solid line refers to ANSI Orange under TUN; the dashed line refers to the "Best" orange (#48) under TUN.



The solid line refers to ANSI Orange under MER: the dashed line refers to the "Best" orange (#48) under MER.

Figure 3. Comparison of spectral reflectance factors of ANSI standard red and orange samples with "best" samples under tungsten illumination and under mercury illumination.

lines in the CIE 1931 (x,y) chromaticity diagram become, in general, curved lines". This space is defined as follows:

$$L^* = 116(Y/Y_n)^{1/3} - 16$$

$$a^* = 500[(X/X_n)^{1/3} - (Y/Y_n)^{1/3}]$$

$$b^* = 200[(Y/Y_n)^{1/3} - (Z/Z_n)^{1/3}], \text{ where}$$

$$X/X_n,\ Y/Y_n,\ Z/Z_n > 0.01.$$

In the above formulae, the quantities X, Y, and Z represent the CIE 1931 tristimulus values, while X_n, Y_n, and Z_n represent tristimulus values of an ideal white sample (a perfectly reflecting diffuser represented in the presented experiment by the PTFE standard) - illuminated by the same light source in the same geometry.

Robertson (1977) compared both CIELUV and CIELAB and found that Munsell loci of constant hue and chroma were represented somewhat more accurately in CIELAB. He noted, however, that neither formula was completely accurate in representing color differences so that users should use their own best judgement in selecting a color difference space. Nevertheless, the CIELAB space has become widely used for industrial applications such as textiles and dyestuffs, and for surface colors in general. As such it appears more appropriate for presenting data on safety colors than does the CIELUV space, which is now more widely used for data on self-luminous colors. Consequently, the data discussed in this report are presented in a CIE a*b* space to demonstrate variations in color space as a function of illuminant.

Figures 4-6 present data for the 10 ANSI samples as calculated for each source, while figures 7-8 present data for the "best" samples as measured under the seven sources actually used in the experiment. These plots demonstrate shifts in chromaticity as a function of illuminant which mirror the shifts in dominant color name found in the psychophysical portion of the experiment.

The CIELAB data discussed above can be compared with the psychophysical data for color naming. For each sample and illuminant combination, Table 3B of the appendix presents the CIELAB data, the dominant color name and frequency, the primary hue and percentage, the secondary hue and percentage, and the median lightness and saturation. Table 3B, thus, can be examined for detailed information about changes in primary and secondary hue, lightness and saturation, as well as changes in CIELAB values for all samples under each source. Further comparisons can be made by examining figures 4-8 which also show the dominant color name given for each sample.

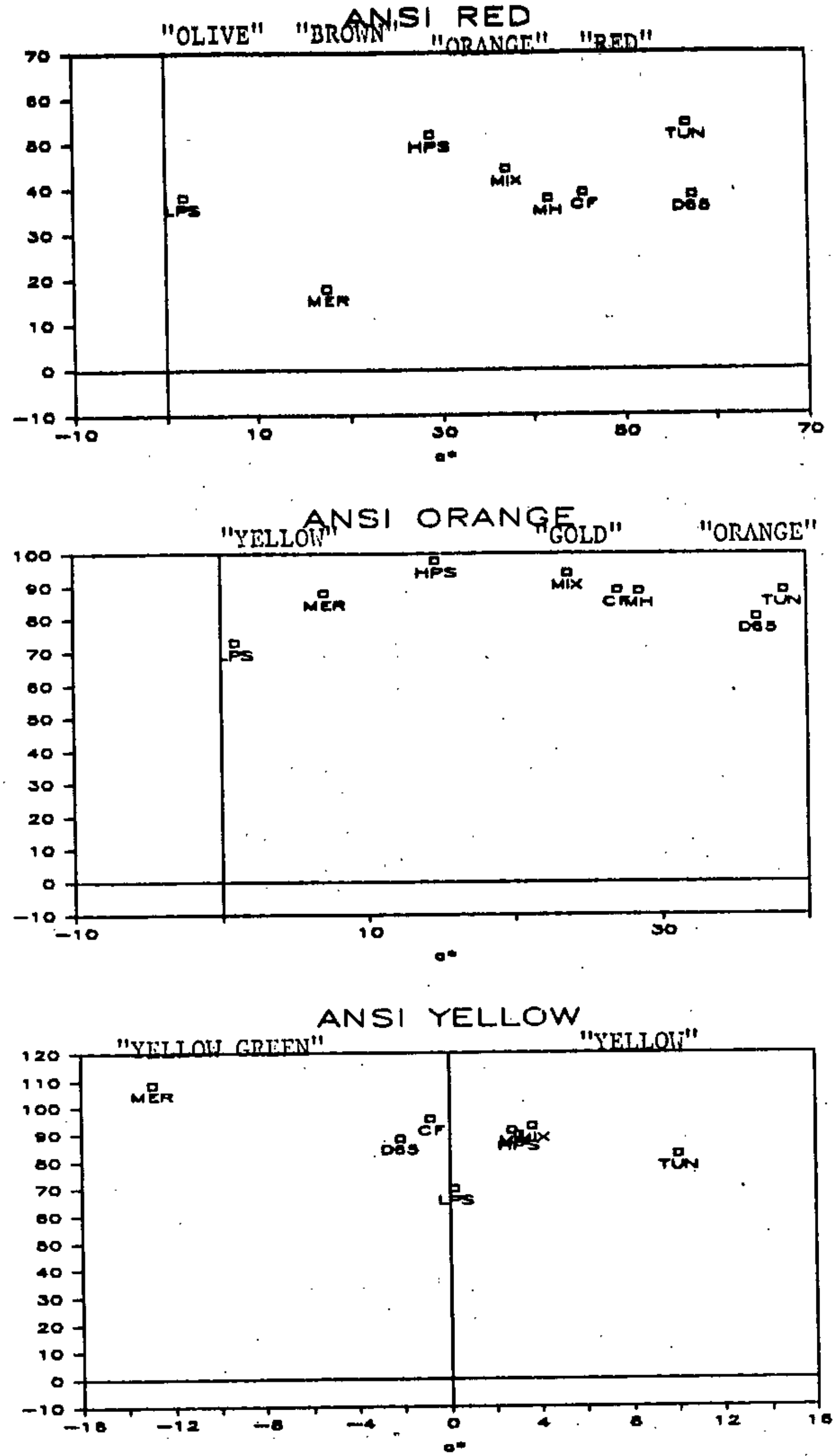


Figure 4. ANSI Red, Orange, and Yellow samples under different illuminants including D_{65} in CIE a*b* space. Color names in quotes refer to the dominant color name given by the observers for the sample under each source in the psychophysical experiment.

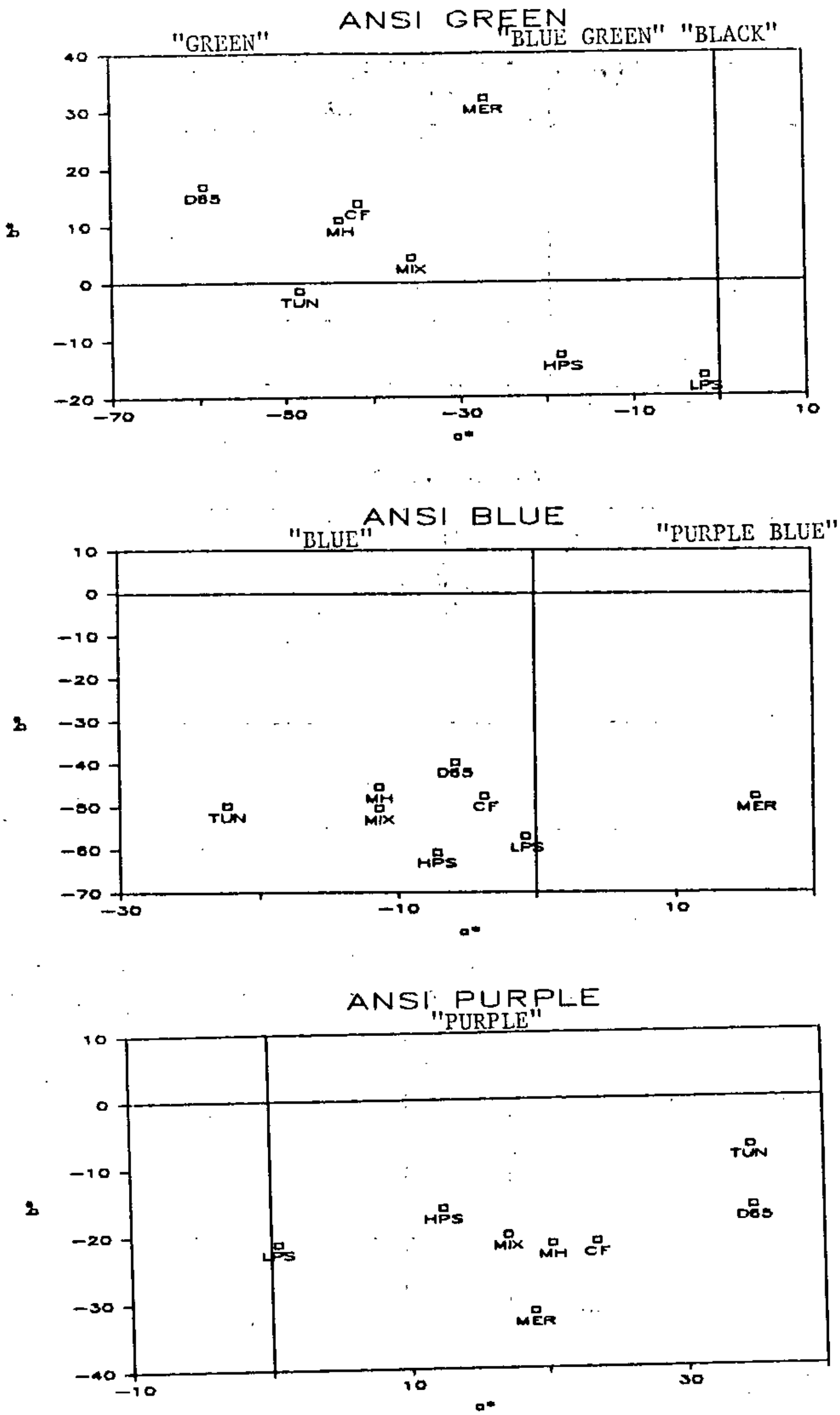


Figure 5. ANSI Green, Blue, and Purple samples under different illuminants including D_{65} in CIE a*b* space. Color names in quotes refer to the dominant color name given by the observers for the sample under each source in the psychophysical experiment.

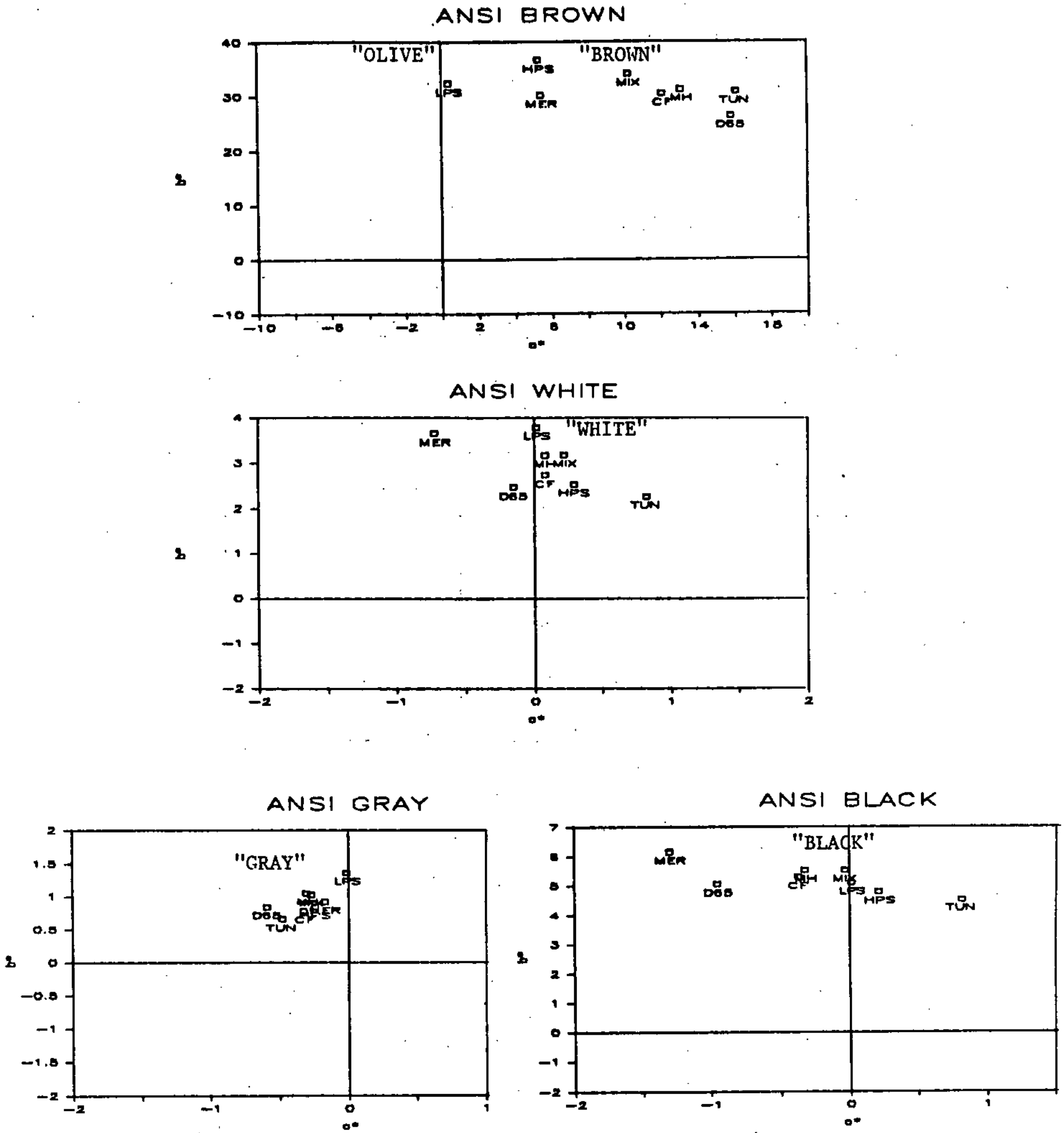


Figure 6. ANSI Brown, White, Gray and Black samples under different illuminants including D_{65} in CIE a*b* space. Color names in quotes refer to the dominant color name given by the observers for the sample under each source in the psychophysical experiment.

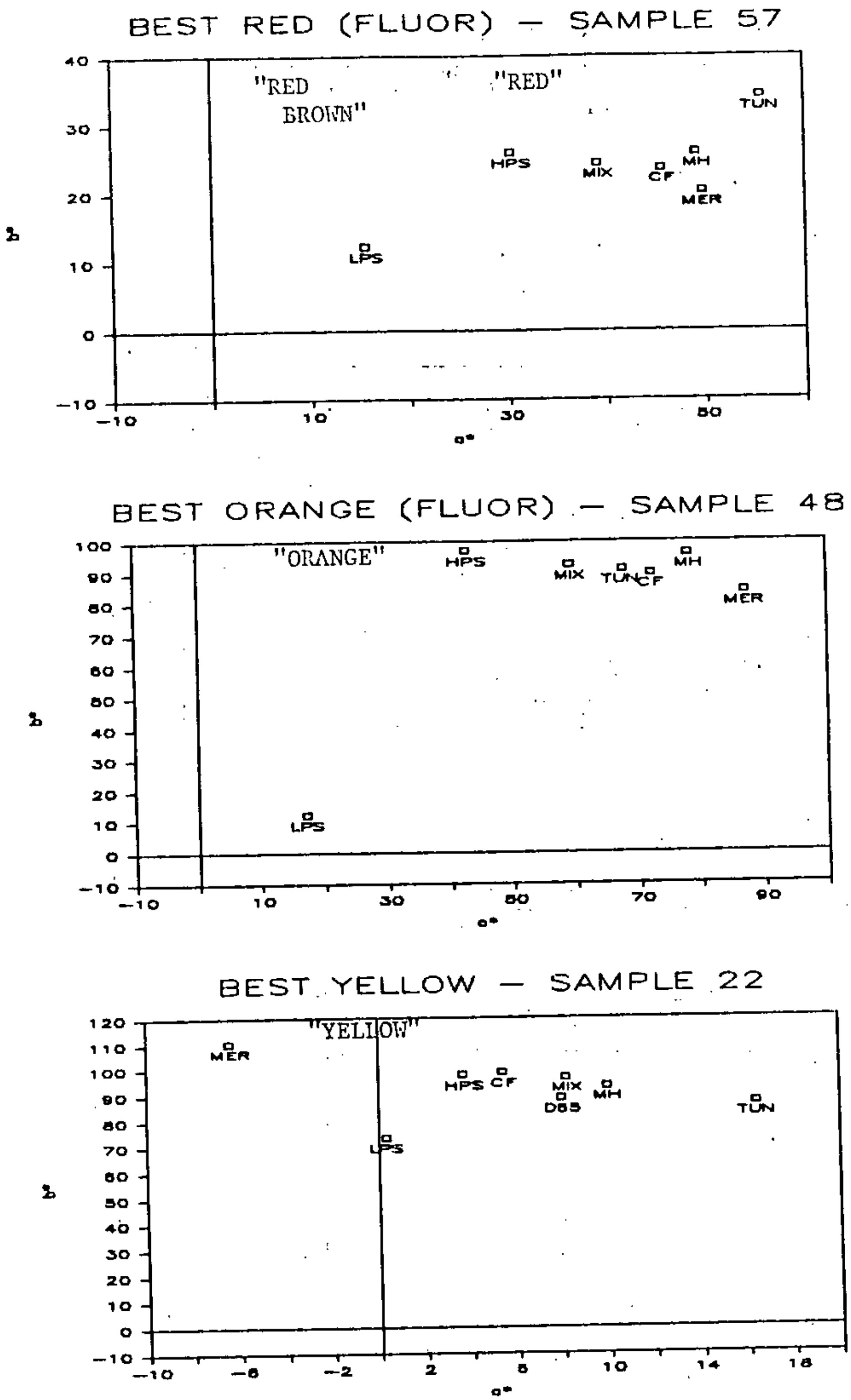


Figure 7. "Best" Red, Orange, and Yellow samples under different illuminants including D_{65} in CIE a*b* space. Color names in quotes refer to the dominant color name given by the observers for the sample under each source in the psychophysical experiment.

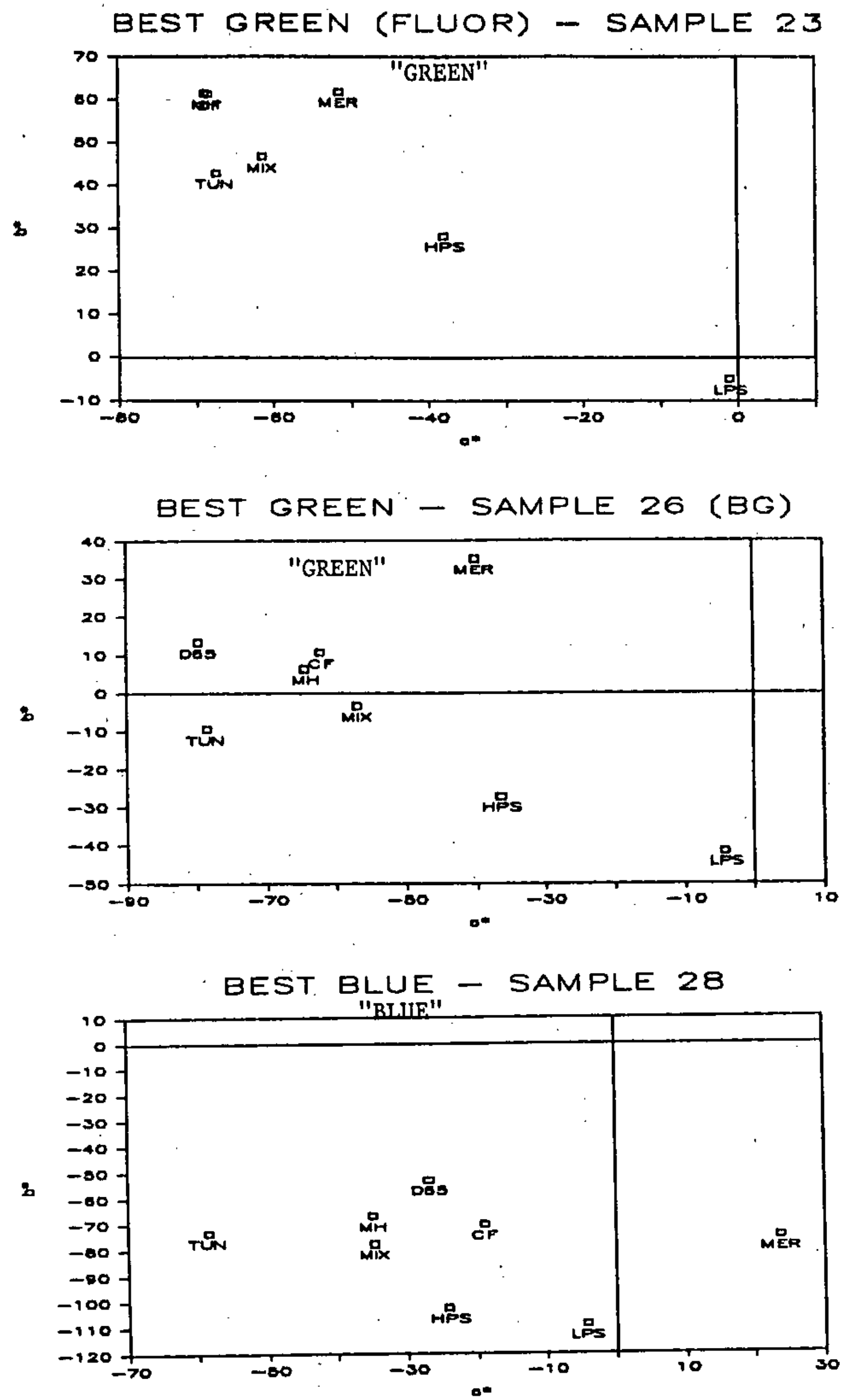


Figure 8. "Best" Green (yellow-green), Green (blue-green), and Blue samples under different illuminants including D_{65} in CIE a*b* space. Color names in quotes refer to the dominant color name given by the observers for the sample under each source in the psychophysical experiment.

Placement of the dominant color name for the ANSI standard samples relative to the a*b* values for these samples measured under TUN can serve as a reference for the other six sources. Examination of figure 4 indicates that ANSI red is seen as red only under TUN, CW and D_{65}. It shifts to orange for HPS, HPSMH, and MH, to brown for MER, and to olive for LPS. Similarly ANSI orange shifts to gold for HPSMH and yellow for HPS, MER, and LPS, while ANSI yellow shifts to yellow green under MER. Figure 5 demonstrates that ANSI green, ANSI blue, and ANSI purple shifts towards black or grey under LPS, while ANSI blue also shifts toward purple blue under MER. By comparison, the shifts in figures 7 and 8 are much less pronounced, with the only shift being that of red-57 toward red brown, and green-23 and 26 toward olive or grey under LPS.

4.3 Gamut of Coloration

One way of presenting the effects of an illuminant on a set of colors is in terms of a "gamut" of coloration. In this type of presentation, CIE a*b* values for the six meaningful safety color samples are presented in one graph for each illuminant. Thus, the location of safety red, orange, yellow, green, blue and purple (representing Danger, Warning, Caution, Safety, Information, and Radiation hazard) in a*b* can be shown for each illuminant studied, allowing easy comparison of the effects of each illuminant on the set of safety colors.

The CIELAB space can be thought of as an opponent color space in which the variables a* and b* correspond to the opponent chromatic channels of an opponent-colors model. To a first approximation, positive a* indicates the redness of a color, while negative a* indicates its greenness. Similarly, positive b* corresponds to a color's yellowness and negative b* to its blueness. The separation between two color points in the a*b* diagram indicates the degree of difference between them. A particular case is the distance from the origin (the white point 0,0) which should correlate with saturation and with the difference from neutral. Thus, the larger the difference (or "gamut") between the six plotted points representing the safety colors in CIELAB space, the more discriminable these colors should be, both from each other, and from neutral. Increasing such discriminability is a key objective of a comprehensive safety color system.

Figures 9 and 10 present gamuts of coloration showing the six ANSI safety colors - Red, Orange, Yellow, Green, Blue, and Purple - under the seven sources used in the experiment and the six "best" colors - fluorescent red, fluorescent orange, yellow, fluorescent yellow-green, blue green, and blue. Inspection of

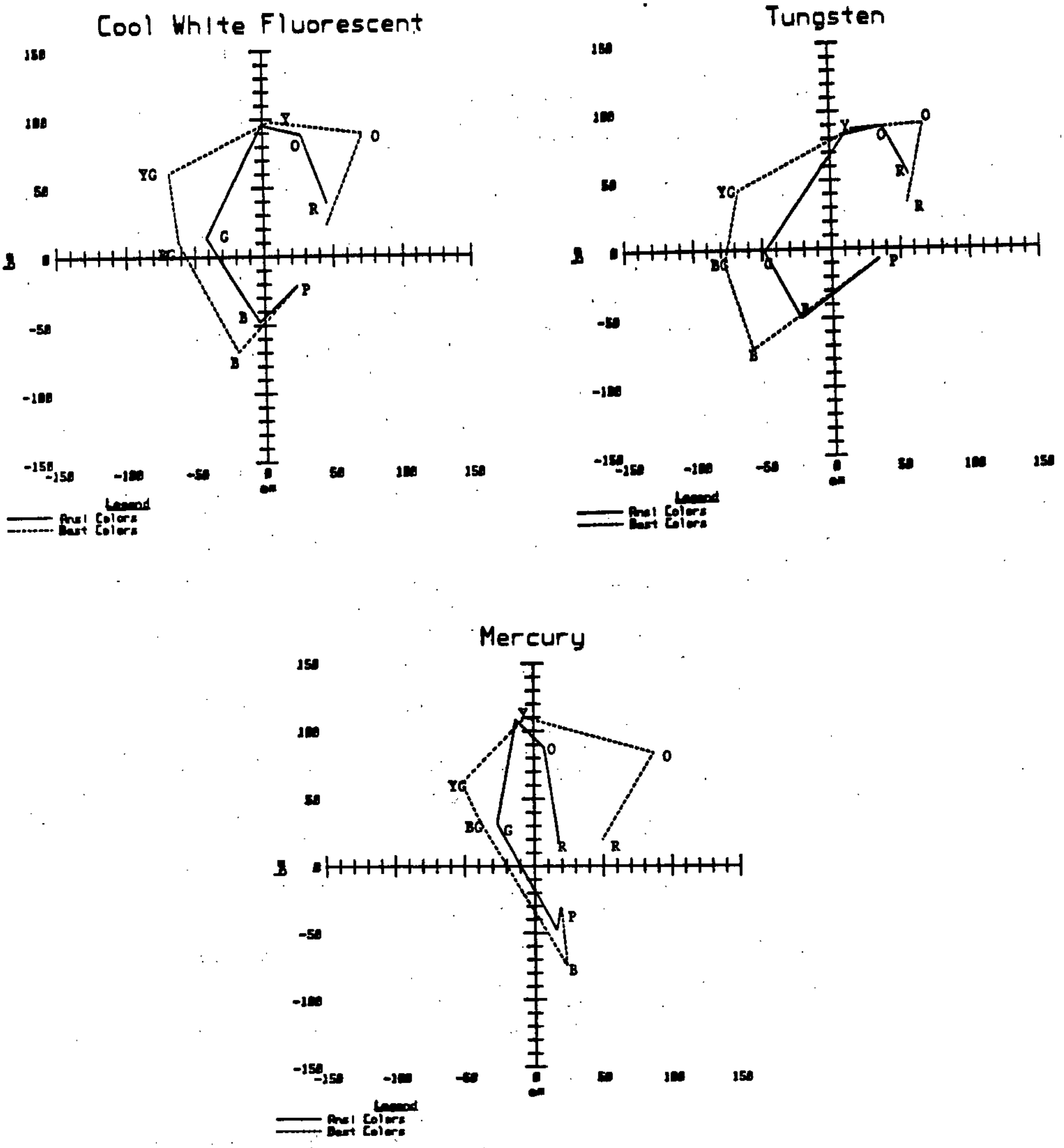


Figure 9. Gamut of coloration for ANSI standard and "Best" samples on a CIELAB a*b* diagram for incandescent, mercury, and cool white fluorescent sources. Letters refer to nominal sample color - red (R), orange (O), yellow (Y), green (G), blue (B) and purple (P).

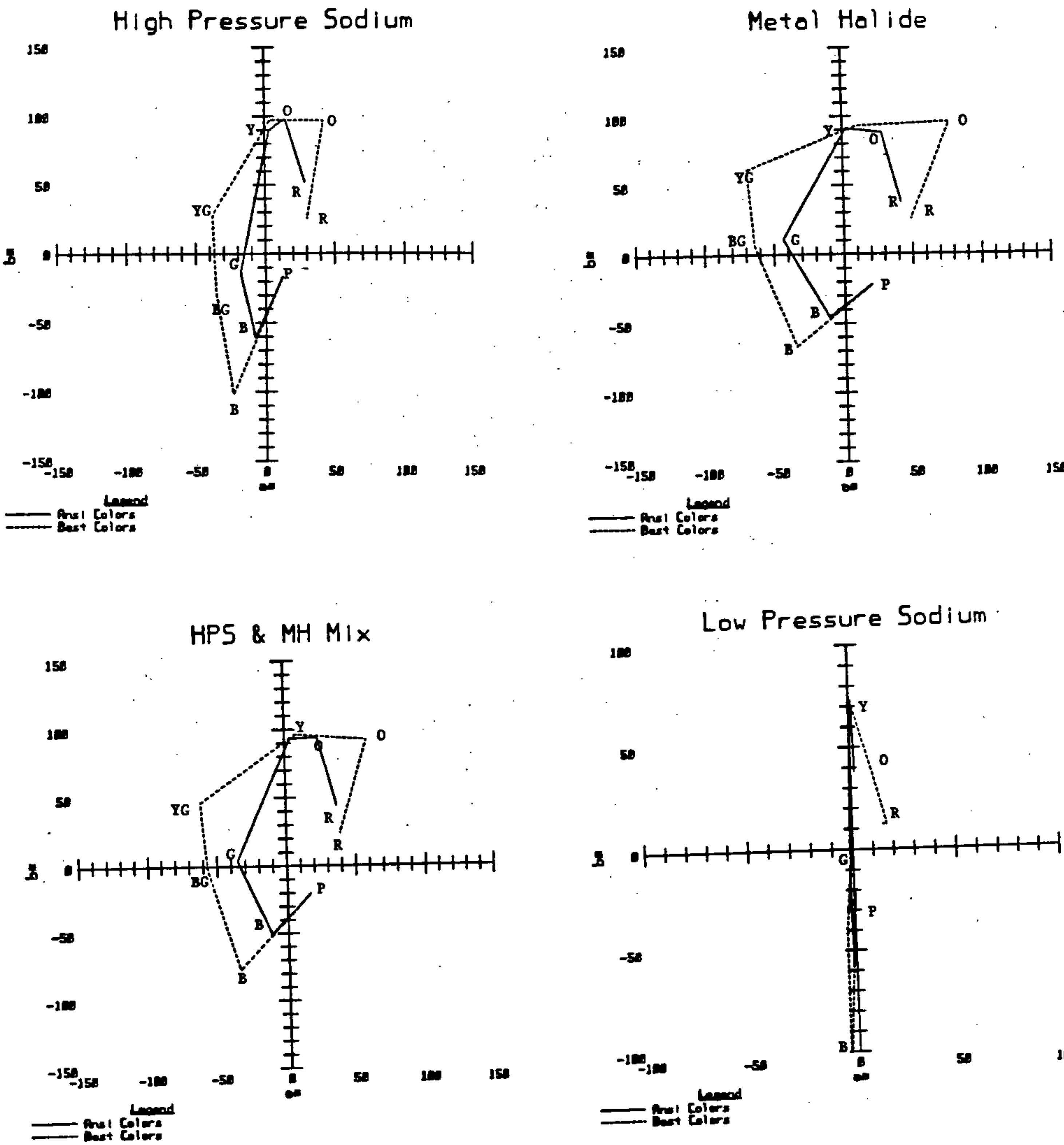


Figure 10. Gamut of coloration for ANSI standard and "Best" samples on a CIELAB a*b* diagram for metal halide, HPSMH mix, HPS, and LPS sources. Letters refer to nominal sample color- red (R), orange (O), yellow (Y), green (G), blue (B) and purple (P).

these figures for the safety colors - shown by the solid lines- reveals that the color gamut shrinks dramatically along the a* axis as one goes from TUN or CWF to HPS and LPS. The collapse of the color gamut in the red-green direction (a* axis) is most apparent for mercury, high pressure sodium, and low pressure sodium. These plots essentially confirm the psychophysical data which had indicated that red and green samples were particularly difficult to identify accurately under these three sources. They also confirm Worthey's (1982; 1985) theory that light sources such as sodium and mercury tend to collapse red-green contrasts.

The gamuts shown in figures 9 and 10 indicate much less collapse along the a* axis for the "best" colors, shown by the dotted lines, even for mercury and high pressure sodium. In fact, figure 9 indicates that the best red and orange samples even have some significant redness under LPS - a statement reinforced by the psychophysical data showing greater accuracy in identifying these two samples under LPS. Figures 9 and 10 indicate that the use of the best samples, including fluorescent ones, is successful in expanding the gamut of coloration for the various HID sources including LPS.

The data collected in the present experiment reinforce the idea that the use of different pigments, including fluorescent ones, is successful in expanding the physical color gamut for safety colors - even for LPS, as well as increasing the accuracy of recognition for these same colors. Nevertheless, even the use of fluorescent or redesigned ordinary pigments is not particularly successful in providing a green which can be recognized as such under LPS.

5. Discussion

5.1 Summary of Psychophysical Results

The preceding discussion of results for each color sample indicates that for many of the safety colors, a new color was identified that was more successful than the original ANSI sample. Typically, these new colors were termed the dominant color name more frequently, had higher percentages of the desired primary color, lower percentages of a secondary color, medium lightness and medium to high saturation - for all seven light sources. The exception to this latter statement arose with LPS where samples tended to have lower lightness and saturation. Nevertheless, examples of red, orange, yellow, blue, and to a lesser extent, green were identified that were accurately recognized under all seven light sources. No totally effective examples for purple, brown, gray, and white were identified because of the poor performance of these sample groups under LPS.

It should be pointed out that LPS is not in widespread use for indoor applications in the U.S. Its use is increasing for outdoor applications such as loading docks, parking lots and highways, however, because of its extremely high efficiency and long life. This means that color coding for nighttime situations must consider whether LPS is likely to be used. Any critical safety messages using color to code information should probably have supplementary high color-rendering lighting when LPS is the primary source.

Performance in the present experiment was also poorer under HPS and MER where the appearance of reds, oranges, and greens was often distorted. There are, however, color corrected versions of both sources now on the market which have higher color rendering indices and should provide better color fidelity. Further research with these sources is needed to determine the effectiveness of individual safety colors. Interestingly, the HPSMH mix was reasonably successful, as was MH alone, with relatively few serious confusions. Nevertheless, even under CW, a widely used source, there were distortions in the standard ANSI colors relative to TUN with red appearing somewhat orange, and orange appearing somewhat yellow.

5.2 Supporting Research

Other researchers have developed and used the concept of color gamut as a way of expressing the impact of a light source on a set of colors. Boyce and Simons (1977) conducted a series of studies involving the effects of light source type and illuminance on a hue discrimination task. The effectiveness of several light sources, including clear mercury, metal halide, and tri-phosphor fluorescents was assessed in terms of both the CIE

Color Rendering Index, and the Color Gamut approach. Boyce and Simons defined the color gamut as the following: "It is not a measure of accuracy of color rendering, rather it is related to the perceptual differences between colours produced by the lamp of interest. The CIE gamut area for a particular lamp, which is the measure to be considered, is defined as the area enclosed in the 1960 CIE-UCS diagram by a line joining the positions of the same 8 standard test colors as are used in the calculation of CRI."

When it is understood that light sources may differ in their ability to make object colors appear saturated, color gamut area is a fairly obvious means to quantify this through calculation. Pracejus (1967) assumed the eight reference colors of the Color Rendering Index to be lit by a variety of lamps, and computed the resulting octagon areas in the 1960 CIE-UCS diagram. To deal with the confounding effect of lamp color, he compared this area with that of a reference source. These measures showed some correlation with "acceptability" of light sources to subjects.

Thornton (1972) proposed computing essentially the same gamut area, divided by a fixed reference area and expressed as a percentage. This number, which he called "Color-Discrimination Index" was to be computed with no adjustment in the color of the reference source, hence no allowance for the color of the lamp being evaluated.

Boyce and Simons (1977) used very much the same idea of color gamut area as Thornton, but since they did an experiment using the 100-hue test, they computed gamut areas in the 1960 CIE-UCS, based on the 85 colored papers of the 100-hue test. Like Thornton, they took no step that would adjust the results according to lamp color. They did find some correlation between illuminant gamut area, and the scores that subjects made on the 100-hue test. Their data are consistent with the results of the present experiment which show changes in color gamut as a function of illuminant.

While it is fairly obvious that color gamut area should show a correlation with color discrimination under various lights, no author has directly addressed the question of the confounding effect of light source color. Without some correction, it will be found that all lights of low color temperature give small gamut areas. Since the visual system tends to correct for illuminant color (Worthey, 1985), some color constancy correction must be in order; this will tend to boost the gamut areas at low color temperature. Pracejus apparently achieved a constancy correction through use of multiple reference illuminants. In the present paper, the correction is intrinsic in the formulas of the CIELAB uniform color space, in which the gamuts are plotted. Like Boyce and Simons, we found that the colors of interest in our experiment naturally formed a polygon in chromaticity; hence, our gamuts are based on those colors, rather than some other reference set.

Data from the present experiment are in general agreement with the predictions made by Thornton (1977) and the data collected by Jerome (1977). They confirm that the ordinary ANSI colors are not accurately recognized under many commonly used sources - particularly HPS and MER. In addition, the present data indicate that it is possible to alter the spectral reflectance distribution of candidate safety colors and improve their recognizability under a wider variety of illuminants.

5.3 Recommendations

The psychophysical and spectral reflectance factor data presented in the preceding sections allow the selection of several new safety colors which are more accurately identified under both HID and common fluorescent sources. The improved colors for red, orange, yellow, green and blue are more readily identifiable under the seven sources studied and can be recommended as serious candidates for new safety colors. In particular, it is possible to recommend a fluorescent red, (57), orange (48), and green (23) sample for use under lighting conditions where the ordinary ANSI color might not be recognized accurately. In addition, ordinary colors which are more effective than the corresponding ANSI safety colors include a yellow (22), a green (26), and a blue (28). No recommended changes can be suggested for safety purple, brown, white, gray, or black. Lighting conditions for which problems in accuracy of recognition might occur include HPS, LPS, MER, and to a lesser extent HPSMH and MH.

One problem with recommending the use of fluorescent colors is that the durability of these colors has not been tested in either outdoor situations or over time. Fluorescent colors degrade faster under some exposure conditions than do ordinary colors, so that the use of special coatings should be explored. Their greater recognizability makes exploration of the durability issue a critical one, however.

In addition to changing the color sample under light sources that distort color, in situations where accurate color recognition is critical, the use of supplementary good color-rendering lighting should be explored. The present experiment demonstrated that the mix of HPS and MH was generally effective in bringing color appearance closer to MH than to HPS. Further experimentation could explore the amount of incandescent, fluorescent, or metal halide lighting necessary to improve the accuracy of color identification under LPS.

The present study has also pointed out that the current ANSI orange and red are often not recognized accurately, and are often confused with each other and with yellow. Such confusions between red, orange, and yellow are potentially serious because of the importance of the safety messages assigned to each color. The data presented here indicate strongly that use of a three-level system for indicating the level of hazard can only be successful if good color rendering light is used.

In conclusion, the present study has demonstrated that the current ANSI colors are not accurately identified when illuminated by many of the most common light sources. To deal with this problem, the present paper has presented a set of color samples which are much more accurately identified under these sources, and which show smaller shift in color gamut using CIELAB values.

6. REFERENCES

1. American National Standards Institute (ANSI). Safety Color Code for Marking Physical Hazards, Z53.1, 1979.

2. American National Standards Institute (ANSI). Specifications for Accident Prevention Signs, Z35.1, 1972.

3. Boyce, P.R. and Simons, R.H. Hue Discrimination and Light Sources, Lighting Research and Technology, 9, pp. 125-140, 1977.

4. Boyce, P.R. Illuminance, Lamp Type and Performance on a Colour Discrimination Task. The Electricity Council Research Center, ECRC/M-943, NTIS PB-276 753, June 1976.

5. Code of Federal Regulations, Title 29, Labor Chapter XVII, Occupational Safety and Health Administration, 1981.

6. Commission Internationale de l'Eclairage (CIE). Recommendations on Uniform Color Spaces, Color Difference Equations, and Psychometric Color Terms. Supplement No.2 to CIE Publication No. 15 (E-1.3.1) 1971/(TC-1.3), 1978.

7. Cornsweet, T.N. Visual Perception, New York: Academic Press, 1970.

8. Glass, R.A., Howett, G.L., Lister, K., and Collins, B.L. Some Criteria for Color and Signs in Workplaces. NBSIR 83-2694, April, 1983.

9. Illuminating Engineering Society of North America. IES Lighting Handbook, Reference Volume. New York, New York, 1984.

10. Jerome, C.W. The Rendering of ANSI Safety Colors, Journal of the Illuminating Engineering Society, 6, pp. 180-183, 1977.

11. Judd, D.B. The Color Perceptions of Deuteranopic and Protanopic Observers, Journal of the Optical Society of America, 39, pp. 252-256, 1949.

12. Munsell Book of Colors, Glossy Finish, Baltimore: Munsell Color Company, 1976.

13. Pracejus, W.G. Preliminary Report on a New Approach to Color Acceptance Studies. Illuminating Engineering, 62, pp. 663-673, 1967.

14. Robertson, A.R. The CIE 1976 Color-Difference Formulae. Color Research and Application, 2, pp. 7-11, 1977.

15. Thornton, W.A. Color Discrimination Index. Journal of the Optical Society of America, 62, pp. 191-194, 1972.

16. Thornton, W.A. The Design of Safety Colors. Journal of the Illuminating Engineering Society, 6, pp. 92-99, 1977.

17. Weidner, V.R., and Hsia, J.J. Reflection Properties of Pressed Polytetrafluoroethylene Power. Journal of the Optical Society of America, 7, pp. 856-861, 1981.

18. Worthey, J.A. Opponent-Colors Approach to Color Rendering, Journal of the Optical Society of America, 72, pp. 74-82, 1982.

19. Worthey, J.A. Limitations of Color Constancy. Journal of the Optical Society of America A, 2, pp. 1014-1026, 1985.

20. Wyszecki, G. and Stiles, W.S. Color Science: Concepts and Methods, Quantitative Data and Formulas, New York: Wiley, 1967.

Appendix A. Detailed Psychophysical Results

A.1 Results for Each Nominal Color Name

A.1.1 Red Sample Results

Tables 1A through 11A of the appendix present results for nominally "red" samples. The tables located at the end of this appendix are arranged in numerical sequence with Number 6, the ANSI Red sample, being first. Each table presents the 19 possible color names, the frequency with which the sample number was given that name under each source (CW, HPS, HPSMH, LPS, MER, MH, and TUN, in that order), frequency counts for lightness judgements, again under the seven sources studied, frequency counts for saturation judgements, frequency counts and average percentage judgements for primary hues and for secondary hues. Each table thus allows one to compare the performance of a given sample under the various sources.

Table 1A presents data for ANSI Red sample number 6. For ease in discussing the results, the color name receiving the highest frequency of responses will be termed the "dominant" color name. Inspection of table 5 reveals that red was the dominant color name for sample 6 only under CW and TUN - and that with relatively low frequency. Under HPS and HPSMH the dominant name was orange, under LPS it was olive, under MER it was brown, and under MH it was red orange. The sample had medium lightness under all sources except MER, and medium saturation under all sources except LPS and MER. While red was the most frequently occurring primary hue under all sources except LPS where yellow occurred most frequently, the percentage of red was always below 85%. Yellow was the secondary hue under all sources except LPS (for which green is the secondary). The percentage of yellow was relatively high, ranging from 17% to 31%. Sample 6 is, thus, not a particularly effective safety red for most sources studied.

Similar trends toward orange are found in the data for sample 11 (table 2A), sample 12 (table 3A), sample 13 (table 4A), and sample 14 (table 5A). In fact, samples 13 and 14 should really have been considered as orange or red-orange, since red was never given as their dominant color name.

The data for sample 33 (table 6A) suggest that it is a more effective red than the ANSI standard. Red was the dominant color name under each sources except LPS and MER, and was the primary hue for all sources. The percentage of red primary was high (85% to 88% under LPS and MER to 93-95% for the other 5 sources). Conversely the percentage of yellow as a secondary was low - around 8-17%. Lightness was either medium or low (LPS, MER and MH), while saturation was medium under HPS and MER, low under LPS, and high under all other sources.

Tables 7A, 8A, and 9A present data for samples 34, 45, and 47, all less successful red samples. The pattern of performance for Sample 34 tended to be similar to that for sample 6, with sample 34 being termed red primarily under TUN and CW, and brown under MER. Sample 45, a fluorescent red, tended to be called pink or orange, while sample 47 (also a fluorescent sample) was always termed orange. The latter sample is again a much better orange than a red, having high percentages of yellow secondary.

Tables 10A and 11A present data for some of the most successful red samples, numbers 57 and 58 (both fluorescent). Red was the dominant name for sample 57 under every source, even LPS. It had medium lightness and saturation under all sources except HPS (for which it had low lightness) and LPS (for which it had low saturation). The primary hue was always red (mean percentage 90% or greater), while the secondary hue was yellow under HPS, LPS, and TUN, and blue under the other sources. The percentage of secondary hue was relatively low, however. The pattern of results was similar for sample 58, except that the frequency of dominant color name was somewhat less across sources and the percentage of red as the primary hue was slightly lower.

The performance of the different red samples can also be compared for each light source. Under TUN and MH seven of the eleven samples were termed red, while under CW six were termed red. Only three samples were termed red under HPS, HPSMH, and MER, and only 2 under LPS. Across light sources, the overall performance was good for samples 58 and 33 but best for sample 57. Red was the dominant name and primary hue for these three fluorescent samples under most sources. All had medium saturation and lightness, and relatively small percentages of blue or yellow as the secondary hue. For sample 57, however, the percentage of red as the primary hue was always above 90%, with all participants giving red as the primary hue and many giving red as the dominant color name. As a result, it can be considered as a good candidate for safety red, replacing the ANSI standard (sample 6).

A.1.2 Orange Sample Results

Tables 13A through 21A present data for nominally orange samples. The color "Orange" can be considered as a 50-50 mixture of red and yellow. Table 13A indicates that sample 5, the ANSI standard, was not a particularly successful orange, receiving orange as the dominant color name only under CW, HPSMH, MH and TUN. Under HPS, LPS and MER, this sample was termed yellow, and even under CW it received a number of mentions of gold as the dominant color name. Yellow was also the primary hue under all sources, ranging from 72-76% under CW, MH and TUN to 96% under LPS. The percentage of red as a secondary hue varied from a low of 6% under LPS to a high of 28% under CW and MH. The sample had medium lightness and medium to high saturation for all sources.

The data for samples 15 and 16, given in tables 14A and 15A, suggest that these are more successful orange samples. In fact, sample 15 was given orange as the dominant color name under all sources with a frequency of 17 or greater, and had medium lightness and medium to high saturation for all sources. In addition, the primary and secondary hues were almost evenly divided between yellow and red. Although sample 16 is a fluorescent version of the retroreflective-fluorescent sample 15, it was a less successful orange under LPS, where it shifted toward yellow. The primary hue for this sample was always yellow, with red as a smaller secondary. Both lightness and saturation were medium to high. Samples 17 and 18, which are retroreflective and ordinary versions of the same nominal pigment, were even less successful oranges. Each had a lower frequency of orange as the dominant color name and a greater tendency toward yellow as the primary hue. Sample 17 was characterized by a shift in dominant color name to gold under LPS and brown under MER and fluctuation in primary hue between yellow and red depending on illuminant. The primary hue for sample 18 was yellow, regardless of source.

Sample 35 (table 16A) also showed a strong shift toward yellow as the dominant color name for LPS and MER with yellow as the primary hue under all sources, and relatively small percentages (7-31%) of red as the secondary hue.

Sample 42 (table 17A), however, was termed orange under all sources with a frequency of 17 or more. Its primary hue was red for all sources except LPS and HPS, while the secondary was yellow at relatively high percentages (39-45%) meaning that this sample is an orange that is neither noticeably red nor yellow. The sample had medium lightness under all sources and high saturation for all except LPS.

The next orange sample, 46 (table 18A), was clearly a red orange rather than a true orange. Only under LPS and HPS was it termed orange with a high frequency. Under the other sources it tended to be termed red, red orange, or orange red. The primary hue was red with relatively small amounts of yellow as a secondary (except under HPS and LPS). The sample had medium lightness and high saturation.

The final two samples to be considered, 48 and 56, (tables 19A and 20A) are some of the best examples of an orange that is neither red nor yellow. Sample 48, a fluorescent sample, was termed orange with a frequency of 18 or greater for all sources. Its primary hue was red (55 to 60%), while its secondary was yellow (40-42%), except for LPS where the primary hue was yellow (69%) and the secondary was red (31%). Lightness was medium, and saturation was high (except for LPS). Although sample 56 was also a good orange, its performance was poorer under LPS where the frequency of orange as the dominant color name dropped to 13 and the saturation dropped to low. The primary hue also shifted to yellow for HPSMH, LPS, MER, and TUN at percentages of 60 to 77%.

Performance for the different orange samples can also be compared for all seven light sources. All ten samples were termed orange under TUN, CW, and HPSMH, while 9 samples were termed orange under HPS and MH. Under HPS, only the ANSI standard, sample 5, was not termed orange. Under MER and LPS, only 5 samples were termed orange. When data for the seven light sources are compared, samples 15, 42, and 48 were consistently seen as orange with both red and yellow as nearly equal hue contributors. Of the nine orange samples studied, however, sample 48 is one of the best candidates for safety orange, having orange as the dominant color name and relatively even mixtures of red and yellow as the primary and secondary hue - for all sources including LPS. Its performance was even better than that for samples 42 and 15, which were also good examples of orange.

A.1.3 Yellow Sample Results

Eight yellow samples were studied (tables 22A-29A) in an attempt to find a yellow which is neither red nor green, but pure yellow. The ANSI sample (4) given in table 22A came close to meeting this criterion, except under MER, where its dominant color name shifted to yellow green. This shift was reflected in the primary hue data, where the percentage of yellow was above 90% for all sources except MER. Although green was the secondary hue for all sources, the percentage of green was higher (18%) under MER. Sample 4 had high lightness (except for TUN) and medium to high saturation.

The shift to yellow green was even more apparent for the next two samples, 19 and 20 (tables 23A and 24A). These are retroreflective fluorescent and fluorescent versions of the same basic pigment. Sample 19, the RF version, was markedly more yellow green, being termed yellow mainly under LPS. Although its primary hue was yellow (71-95%), this sample had high percentages of green as the secondary hue (14-31%). Both lightness and saturation were high (except under LPS and HPSMH). Sample 20 was somewhat more successful being termed yellow green only under CW and MER. Its primary hue was yellow (81-97%), with green as the secondary hue (12-19%). This sample always had high lightness and saturation.

Samples 21 and 22 (tables 25A and 26A) are retroreflective and ordinary versions of the same pigment. Sample 21 tended to be termed yellow under HPS, LPS and MER, and yellow, orange, and gold under CW, HPSMH, MH, and TUN. Its primary hue was generally a high percentage of yellow (85-97%), while the secondary hue shifted between red and green depending on the source. Both lightness and saturation were medium.

Unlike the other three samples in its series, sample 22 had yellow as the dominant color name for all sources, including MER. The percentage of yellow as the primary hue was high (92-96%) for all sources. The secondary hue was green under HPS and MER (11-13%), but red under HPSMH, LPS, MH and TUN (7-13%), and either red or green for CW. Sample 22 also had high lightness and saturation, for all seven light sources, making it one of the best examples of yellow studied.

Performance was not as good for the remaining three yellow samples. While sample 36 (table 27A) had yellow as the dominant color name for all sources, the frequency was much lower than for sample 22. The percentage of yellow as the primary hue was slightly lower (85-96%, with only LPS and CW above 90%). The secondary hue was red under HPSMH and TUN and green for all other sources (9-19%). Both lightness and saturation were medium for all sources. For sample 37 (table 28A), the dominant color name shifted toward tan for CW, HPSMH, MH, and TUN, and to yellow for HPS and LPS. While yellow was the primary hue for all sources, the percentage was somewhat low (88-92%), while the percentage of green as a secondary hue was high (9-16%). Lightness was medium, but saturation was low, except under CW, HPS, and LPS. The performance was even poorer for sample 49 (table 29A), which was termed orange for all sources except LPS. The percentage of yellow as the primary hue also dropped to between 64 and 75% for all sources except LPS, while the percentage of red as the secondary hue increased to between 25 and 36%. Lightness was medium to high, while saturation was high.

Again, performance for the various samples may be compared for all seven light sources. Only under LPS were all eight yellow samples termed yellow, although under HPS seven samples were termed yellow. Under MH five samples were termed yellow, while under TUN, CW, and MER only four samples were termed yellow. Under many of these sources the yellows shifted toward green, or to a lesser extent, toward orange.

Of the yellow samples studied, the best performance for all light sources was obtained for samples 4 and 22. Performance for the latter was superior in that it was termed yellow even under mercury and had a somewhat higher percentage of yellow as the primary hue. It consistently had medium to high saturation and lightness, with relatively little green or red as a secondary hue. Sample 22 thus appears to be the best candidate for an effective safety yellow. The ANSI sample, 4, is a good candidate except for its somewhat yellow-green appearance under clear mercury.

A.1.4 Green Sample Results

The next series of tables, 30A-39A present data for the ten nominally green samples. Table 30A gives the data for the ANSI standard, sample 3. The dominant color name for this sample was green or blue green, except under LPS, where it was termed gray. Although the primary hue was green (84-89%), blue was a strong secondary hue (20-53%) under most sources. It should be noted that the ANSI Green was deliberately designed to be a blue-green rather than a yellow green to avoid red green confusions by color defective observers. Consequently, the strong blue secondary hue noted by the observers in the present experiment is line with this intention. Sample 3 also had medium lightness, (low under LPS and HPS), and medium saturation (low under MER.) If the green and blue-green responses are combined, sample 3 is a reasonably effective green, except under LPS.

Sample 23 (table 31A) is an another example of a good green, being termed green under all sources, except LPS, where it was termed olive. It did receive two mentions of green under LPS, however. Under all sources, its primary hue was green (78-92%), and the secondary hue was yellow (13-24%), meaning that this green was considerably yellower and less blue than the ANSI standard green. It had medium lightness and medium to high saturation (except under LPS). Sample 24 (table 32A) is an example of an even yellower green with yellow green being a strong contender for the dominant color name under most sources. Its primary hue was green (76-84%) for all sources except LPS, while the secondary hue was yellow (18 to 24%). Sample 24 had medium to high lightness and saturation for all sources except LPS.

Sample 25 (table 33A) is another sample which was given green or blue green as a dominant color name for all sources except LPS, where it was termed black. The primary hue was green (74-92%) (blue for HPS), while the secondary hue was blue (12-28%) Its lightness was medium to low and its saturation was medium for all sources. A similar pattern of responses was obtained for sample 26 (table 34A, except that this sample also received two olive responses under LPS. Its primary hue was green even under LPS, (range of 79-95%) and the secondary hue was blue (range 19-25%) for all sources except LPS where it was yellow. Its lightness and saturation were medium for all sources (low under LPS). The performance for sample 26 compares favorably with that for sample 3 having about equal frequencies of green or blue green as the dominant color name, similar percentages of green as the primary hue, but slightly lower percentages of blue as the secondary hue. Sample 26 was also more consistently seen as having medium lightness and saturation than sample 3. As a result, sample 26 appears to be a reasonable candidate to replace sample 3 if a blue green is desired.

Sample 39 (table 35A) is another example of a blue green where the dominant color name tended to be green or blue green. Under LPS, however, this sample was termed blue. The primary hue was green (range 62-93%), although it was blue or blue green under LPS and HPS. The secondary hue was blue with a range of 7 to 38%. Lightness was generally low to medium, while saturation was medium.

Sample 40 (table 36A) is a yellow green with a dominant color name of yellow or yellow green. The primary hue was yellow (range 74-97%) while the secondary hue was green (range 10 to 26%). Lightness was high (except for LPS), while saturation was medium to high. Sample 50 (table 37A) is also a yellow green with yellow being the primary hue (74-98%) and green the secondary (16-26%). This sample was completely yellow under LPS and also had high lightness and saturation. Sample 51 (table 38A) represents a return to somewhat greener samples, although it still received a number of yellow and yellow green responses for dominant color. The primary hue was green (78-86%) except for LPS where it was yellow, while the secondary hue was yellow (16-25%). Lightness was medium, while saturation was high for CW, MH, and TUN; medium for HPS, HPSMH, and MER; and low for LPS.

Sample 55 (table 39A) is the sample that was the best green in the Glass, et al, (1982) experiment. It is a good example of a blue green for all sources except LPS, where it was termed black or gray. The primary hue was green (79-89%) while the secondary hue was blue (14-22%). Unlike sample 26, however, the lightness was medium to low.. Saturation was medium except under LPS.

Under all light sources, green is one of the more difficult samples to identify accurately. The ANSI Standard, 3, was never seen as the best green, and often not seen as green at all under some sources. If blue green and green responses for dominant color name are combined, then 9 of the ten green samples were termed green under HPS, 8 under TUN, MH, and MER, 7 under CW, and 6 under Mer. Under LPS 3 green samples were termed olive.

Of the green samples studied, sample 26 appears to be a good candidate for safety green, and is consistent with the philosophy of using a blue green to avoid red-green color confusions. In addition, it is not a fluorescent color so it avoids the potential durability problems that can occur with fluorescent pigments. If a yellower green is desired, then sample 23 appears to be a good candidate, particularly since it received two green responses under LPS. Nevertheless, the picture for green perception under LPS is very dismal. If the color green needs to be perceived as such under this source, supplemental lighting with a better color-rendering source must be used.

Selecting between samples 23 and 26 is difficult because the two samples are quite different. Sample 23 appears to be closer to a green that is termed neither blue nor yellow, but sample 26 appears to be closer to the original ANSI desire to separate green and red as much as possible to avoid confusions by color defective observers.

A.1.5 Blue Sample Results

Unlike green, blue was one of the most successful colors for all light sources, having a high frequency of correct dominant color name and high percentage of blue as the primary hue. Tables 40A-45A present data for the five blue samples studied. Data for ANSI sample 2 are given in table 40A. This sample was always termed blue except under MER, and LPS (where it was never termed blue). Its primary hue was blue with percentages as high as 97-99%, while the secondary hue was generally a low percentage of red (except for TUN where it was green). Lightness was medium to low, while saturation was medium (low for LPS). This pattern of responses was similar for sample 27 (table 41A) which was termed black under LPS, while receiving extremely high percentages of blue as the primary hue and small percentages of red or green as the secondary hue.

Sample 28 (table 42A), however, was termed blue under all sources, including LPS. It was one of the only blue samples termed blue under LPS. Its primary hue was blue (95-98%) for all sources while its secondary hue was green (8-13%) except for MER where it was red (10%). Lightness was medium and saturation was high except for LPS. Thus, sample 28 is a good candidate for safety blue.

Although sample 40 (table 43A) was termed blue under most sources, it was not a very successful blue under LPS. While it received a high percentage of blue as a primary hue under the other sources (and small percentages of red as a secondary hue), its lightness was low for all sources. Its saturation was generally high except for LPS and MER. Similarly, samples 52 and 54 (tables 44A and 45A) showed excellent performance for all sources except LPS. Under that source they were rarely termed blue, had low or non-existent percentages of blue as the primary hue, and had low saturation and lightness. Under the other sources they had high (96-99%) percentages of blue as the primary hue, and low percentages of red or green as the secondary hue. Sample 52 had medium lightness and saturation, while sample 54 had low lightness and medium to high saturation.

When performance for different sources is compared, all five samples were termed blue under TUN, CW, HPS, HPSMH, and MH, with blue being given as the primary hue 97-99% of the time. Under MER, the picture for blue changes slightly with only sample 52 termed blue by all observers. Samples 28, 27, 40 and 54 were termed blue by 18 to 19 observers with percentage of blue as the primary hue between 94 and 97%. Sample 2, however, was seen as blue only 12 times with a secondary hue of red (16%). Under LPS only sample 28 was termed blue. While this sample had low saturation and lightness, its primary hue was given as blue 14 times with a percentage of 99. All other blue samples were seen as black or gray.

Thus, the most successful blue sample is 28, although this characterization is only true when all seven sources are considered. Again, the ANSI Blue (2) was less successful, having poor identification as blue under mercury and LPS. Sample 28 had medium lightness and high saturation under all sources except clear mercury when the saturation dropped to medium, and LPS where both lightness and saturation were low.

A.1.6 Purple/Magenta Sample Results

Tables 46A-50A present data for the five samples studied for safety purple. Only sample 1, the ANSI standard, emerged as a good candidate for safety purple across light sources; all other samples were termed magenta or pink but never purple.

Table 46A indicates that sample 1 was termed purple under all sources except LPS, where it was termed gray, brown, tan, or olive. Its primary hue was red under HPS and TUN (61-75%), blue under HPSMH, MER, MH (59-65%), split between red and blue under CW, and green under LPS. This sample had medium lightness and medium saturation (except for LPS). Samples 29, 30, 44, and 53 (tables 47A to 50A) were successful pinks, receiving pink as the dominant color name for most sources - and never receiving pink, purple, or magenta as the dominant name under LPS. Under LPS they tended to be termed orange, yellow, or red. Under the other six light sources, the samples varied in the proportion of red and blue mixtures, but all had red as the primary hue and blue as the secondary. Samples 29 and 30 had generally high lightness and saturation, while samples 44 and 53 tended to have medium lightness and high saturation.

Regardless of light source, none of the new samples studied is an effective replacement for the ANSI standard purple. In addition, no sample, including ANSI purple, was an effective purple or magenta under LPS. If purple is needed to transmit a message, such as radiation hazard, supplemental lighting with a better color rendering source must be used.

A.1.7 Brown, White, Gray and Black Sample Results

Results for safety brown, white, gray and black will be discussed together since only a few samples were studied for each color name.

Two samples were studied for brown, samples 7 and 38, presented in tables 51A and 52A. There was little difference in performance between the two samples, with both being termed brown under all sources except LPS, and tan or olive under LPS. Performance was somewhat poorer for HPS and MER which are frequently termed olive, even though the dominant color name was brown. Under CW, HPSMH, MH, and TUN, red was the primary hue for both samples, while under HPS, MER, and LPS it tended to be green. For all sources, the secondary hue was generally yellow. Both samples had generally low lightness and saturation. As a result, there appears to be no reason to switch from the ANSI standard to a different brown. Although neither brown was accurately recognized as such under LPS, both samples tended to be termed tan or olive which could be interpreted as brownish shades.

Four examples of white were studied - samples 10, 31, 32, and 41, presented in tables 53A-56A. Performance was very similar for samples 10 and 32 which were almost always termed white under all sources except LPS. Under LPS they were always termed yellow. These two samples had high lightness and no saturation, except under LPS where they were seen as highly saturated. Sample 31 was termed gray for all sources except under LPS where it was termed yellow. The pattern of responses was mixed for sample 41. It was termed gray under CW and MH, yellow under LPS, and white under the remaining light sources. It had high lightness except under LPS where it also had medium saturation. Only two candidates for white (samples 10 and 32) were successful with about equally good performance so that sample 10, the ANSI sample, continues to be a reasonable Safety White. It should be noted, however, that no white sample was recognized as such under LPS. Rather, each was termed yellow. As a result, it appears likely that a white sign on a black background under LPS might well be interpreted as a Caution message in yellow and black. Again, the use of supplementary, good color rendering light is essential if white is to be distinguished from yellow in critical situations.

One example each of gray (table 57A) and black (table 58A) was studied. Results for gray were similar to those for white, with confusions with yellow and olive under LPS and accurate recognition under all other sources. As might be expected, gray had medium lightness and no saturation (except under LPS where it had low saturation). Black was consistently termed black for all sources with low lightness and no saturation.

A detailed tabulation of the results for each color sample is presented in the following pages. Results for the red samples are given first, followed by those for the orange, yellow, green, blue, purple, brown, white, grey, and black samples in Tables 1A-58A.

Table 1A. Results for Sample 6, ANSI Red.[1]

OSHA COLOR SAMPLE NO. 6

COLOR NAME	FREQUENCY						
	CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	11	0	2	0	0	6	12
RED ORANGE	2	1	5	0	0	7	4
ORANGE RED	1	1	1	0	0	2	1
PINK	0	0	0	0	0	0	0
ORANGE	5	15	9	0	0	4	3
GOLD	0	0	0	1	0	0	0
YELLOW	0	0	0	3	0	0	0
YELLOW GREEN	0	0	0	2	0	0	0
TAN	0	1	0	4	0	0	0
OLIVE	0	0	0	8	0	0	0
GREEN	0	0	0	1	0	0	0
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	0	0	0	0	0	0	0
MAGENTA	0	0	0	0	0	0	0
BROWN	1	2	3	0	20	1	0
GRAY	0	0	0	1	0	0	0
BLACK	0	0	0	0	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY						
	CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	0	1	0	2	0	0	0
MEDIUM	14	10	14	15	3	14	18
LOW	6	9	6	3	17	6	2
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY						
	CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	5	4	5	1	0	3	11
MEDIUM	11	13	10	6	9	14	6
LOW	4	3	5	13	11	3	3
TOTALS	20	20	20	20	20	20	20

PRIMARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	20	0.85	17	0.69	19	0.74	0	ERR	18	0.82	20	0.79	20	0.85
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	6	0.85	0	ERR	0	ERR	0	ERR
YELLOW	0	ERR	3	0.58	1	0.60	13	0.77	2	0.63	0	ERR	0	ERR
TOTALS	20		20		20		19		20		20		20	

SECONDARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	0	ERR	3	0.42	1	0.40	4	0.26	2	0.38	0	ERR	0	ERR
BLUE	4	0.08	0	ERR	0	ERR	0	ERR	2	0.08	2	0.15	2	0.08
GREEN	0	ERR	0	ERR	0	ERR	8	0.24	2	0.35	0	ERR	0	ERR
YELLOW	15	0.18	17	0.31	19	0.26	6	0.15	12	0.20	17	0.24	17	0.17
TOTALS	19		20		20		18		18		19		19	

[1] In this table AVG% indicates decimal fractions rather than actual percentages and ERR simply means no data exist for a given entry.

Table 2A. Results for Sample 11, Retroreflective Red.

OSHA COLOR SAMPLE NO. 11

COLOR NAME	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	14	0	4	0	6	12	13
RED ORANGE	2	3	5	0	0	2	3
ORANGE RED	2	2	1	0	0	1	2
PINK	0	0	0	0	0	0	0
ORANGE	2	14	8	0	0	3	2
GOLD	0	0	0	1	0	0	0
YELLOW	0	0	0	2	0	0	0
YELLOW GREEN	0	0	0	0	0	0	0
TAN	0	0	0	6	0	0	0
OLIVE	0	0	0	7	0	0	0
GREEN	0	0	0	2	0	0	0
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	0	0	0	0	1	0	0
MAGENTA	0	0	0	0	0	0	0
BROWN	0	1	2	1	13	2	0
GRAY	0	0	0	1	0	0	0
BLACK	0	0	0	0	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	0	0	0	3	0	0	0
MEDIUM	17	15	16	14	1	15	19
LOW	3	5	4	3	19	5	1
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	10	6	6	0	0	8	13
MEDIUM	10	12	12	5	14	9	7
LOW	0	2	2	14	6	3	0
TOTALS	20	20	20	19	20	20	20

PRIMARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	20	0.86	18	0.64	20	0.77	2	0.75	20	0.87	20	0.82	20	0.87
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	7	0.84	0	ERR	0	ERR	0	ERR
YELLOW	0	ERR	2	0.75	0	ERR	10	0.79	0	ERR	0	ERR	0	ERR
TOTALS	20		20		20		19		20		20		20	

SECONDARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	0	ERR	2	0.25	0	ERR	3	0.22	0	ERR	0	ERR	0	ERR
BLUE	3	0.07	0	ERR	0	ERR	0	ERR	6	0.11	2	0.15	2	0.08
GREEN	0	ERR	0	ERR	0	ERR	7	0.22	1	0.30	0	ERR	0	ERR
YELLOW	16	0.17	18	0.36	20	0.24	7	0.21	10	0.16	18	0.18	16	0.16
TOTALS	19		20		20		17		17		20		18	

Table 3A. Results for Sample 12, Ordinary Red.

OSHA COLOR SAMPLE NO: 12

COLOR NAME	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	6	0	0	0	10	8	4
RED ORANGE	6	2	6	0	0	5	5
ORANGE RED	4	0	1	0	0	1	0
PINK	0	0	1	0	1	0	0
ORANGE	4	18	12	1	0	6	11
GOLD	0	0	0	2	0	0	0
YELLOW	0	0	0	10	0	0	0
YELLOW GREEN	0	0	0	1	0	0	0
TAN	0	0	0	3	0	0	0
OLIVE	0	0	0	3	0	0	0
GREEN	0	0	0	0	0	0	0
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	0	0	0	0	4	0	0
MAGENTA	0	0	0	0	2	0	0
BROWN	0	0	0	0	3	0	0
GRAY	0	0	0	0	0	0	0
BLACK	0	0	0	0	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	1	3	1	4	0	0	1
MEDIUM	16	15	19	14	7	19	19
LOW	3	2	0	2	13	1	0
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	11	8	5	0	0	6	17
MEDIUM	8	11	14	10	12	11	3
LOW	1	1	1	10	8	3	0
TOTALS	20	20	20	20	20	20	20

PRIMARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	20	0.78	16	0.61	20	0.71	0	ERR	20	0.85	20	0.81	20	0.71
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	1	0.80	0	ERR	0	ERR	0	ERR
YELLOW	0	ERR	4	0.59	0	ERR	19	0.87	0	ERR	0	ERR	0	ERR
TOTALS	20		20		20		20		20		20		20	

SECONDARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	0	ERR	4	0.41	0	ERR	5	0.18	0	ERR	0	ERR	0	ERR
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	13	0.19	2	0.13	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	11	0.14	0	ERR	0	ERR	0	ERR
YELLOW	20	0.22	16	0.39	20	0.29	1	0.20	5	0.09	16	0.23	20	0.29
TOTALS	20		20		20		17		18		18		20	

Table 4A. Results for Sample 13, Retroreflective-Fluorescent Red Orange.

OSHA COLOR SAMPLE NO. 13

COLOR NAME	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	1	0	3	2	4	4	1
RED ORANGE	5	7	8	5	8	8	5
ORANGE RED	1	1	0	1	0	0	0
PINK	0	0	0	0	0	0	0
ORANGE	13	12	9	12	8	8	14
GOLD	0	0	0	0	0	0	0
YELLOW	0	0	0	0	0	0	0
YELLOW GREEN	0	0	0	0	0	0	0
TAN	0	0	0	0	0	0	0
OLIVE	0	0	0	0	0	0	0
GREEN	0	0	0	0	0	0	0
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	0	0	0	0	0	0	0
MAGENTA	0	0	0	0	0	0	0
BROWN	0	0	0	0	0	0	0
GRAY	0	0	0	0	0	0	0
BLACK	0	0	0	0	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	6	4	5	5	5	8	2
MEDIUM	14	16	14	15	15	12	18
LOW	0	0	1	0	0	0	0
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	18	17	19	16	18	20	16
MEDIUM	2	3	1	4	2	0	4
LOW	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

PRIMARY HUES	CW FREQ	CW AVG%	HPS FREQ	HPS AVG%	HPSMH FREQ	HPSMH AVG%	LPS FREQ	LPS AVG%	MER FREQ	MER AVG%	MH FREQ	MH AVG%	TUN FREQ	TUN AVG%
RED	20	0.68	17	0.65	19	0.67	19	0.71	20	0.70	20	0.69	19	0.63
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
YELLOW	0	ERR	3	0.57	1	0.60	1	0.60	0	ERR	0	ERR	1	0.60
TOTALS	20		20		20		20		20		20		20	

SECONDARY HUES	CW FREQ	CW AVG%	HPS FREQ	HPS AVG%	HPSMH FREQ	HPSMH AVG%	LPS FREQ	LPS AVG%	MER FREQ	MER AVG%	MH FREQ	MH AVG%	TUN FREQ	TUN AVG%
RED	0	ERR	3	0.43	1	0.40	1	0.40	0	ERR	0	ERR	1	0.40
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
YELLOW	20	0.33	17	0.35	19	0.33	19	0.29	20	0.30	20	0.32	19	0.37
TOTALS	20		20		20		20		20		20		20	

Table 5A. Results for Sample 14, Fluorescent Red Orange.

OSHA COLOR SAMPLE NO. 14

COLOR NAME	FREQUENCY						
	CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	3	0	3	0	5	2	3
RED ORANGE	6	3	5	0	6	8	6
ORANGE RED	3	0	0	0	0	1	0
PINK	0	0	0	0	0	0	0
ORANGE	8	17	12	20	9	9	11
GOLD	0	0	0	0	0	0	0
YELLOW	0	0	0	0	0	0	0
YELLOW GREEN	0	0	0	0	0	0	0
TAN	0	0	0	0	0	0	0
OLIVE	0	0	0	0	0	0	0
GREEN	0	0	0	0	0	0	0
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	0	0	0	0	0	0	0
MAGENTA	0	0	0	0	0	0	0
BROWN	0	0	0	0	0	0	0
GRAY	0	0	0	0	0	0	0
BLACK	0	0	0	0	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY						
	CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	4	2	2	0	1	6	4
MEDIUM	16	18	17	18	19	14	16
LOW	0	0	1	2	0	0	0
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY						
	CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	18	15	13	5	9	17	15
MEDIUM	2	5	6	12	10	2	5
LOW	0	0	1	3	1	1	0
TOTALS	20	20	20	20	20	20	20

PRIMARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	20	0.73	16	0.61	18	0.71	16	0.62	19	0.75	20	0.68	18	0.70
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
YELLOW	0	ERR	4	0.58	2	0.60	4	0.63	1	0.60	0	ERR	2	0.55
TOTALS	20		20		20		20		20		20		20	

SECONDARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	0	ERR	4	0.43	2	0.40	4	0.38	1	0.40	0	ERR	2	0.45
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
YELLOW	20	0.27	16	0.39	18	0.29	16	0.38	19	0.25	20	0.32	18	0.30
TOTALS	20		20		20		20		20		20		20	

Table 6A. Results for Sample 33, Retroreflective Dark Red.

OSHA COLOR SAMPLE NO. 33

COLOR NAME	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	20	18	19	0	8	20	19
RED ORANGE	0	0	0	0	0	0	1
ORANGE RED	0	1	1	0	0	0	0
PINK	0	0	0	0	0	0	0
ORANGE	0	0	0	0	0	0	0
GOLD	0	0	0	0	0	0	0
YELLOW	0	0	0	0	0	0	0
YELLOW GREEN	0	0	0	0	0	0	0
TAN	0	0	0	0	0	0	0
OLIVE	0	0	0	0	0	0	0
GREEN	0	0	0	0	0	0	0
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	0	0	0	1	2	0	0
MAGENTA	0	1	0	0	1	0	0
BROWN	0	0	0	13	9	0	0
GRAY	0	0	0	4	0	0	0
BLACK	0	0	0	2	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	2	0	0	0	0	0	0
MEDIUM	11	14	13	5	0	8	19
LOW	7	6	7	15	20	12	1
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	14	7	13	0	2	11	17
MEDIUM	2	11	6	5	12	7	3
LOW	4	2	1	10	6	2	0
TOTALS	20	20	20	15	20	20	20

PRIMARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	20	0.95	20	0.93	20	0.94	11	0.85	20	0.88	20	0.95	20	0.96
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	1	0.70	0	ERR	0	ERR	0	ERR
YELLOW	0	ERR	0	ERR	0	ERR	2	0.75	0	ERR	0	ERR	0	ERR
TOTALS	20		20		20		14		20		20		20	

SECONDARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	0	ERR	0	ERR	0	ERR	2	0.40	0	ERR	0	ERR	0	ERR
BLUE	4	0.09	2	0.10	3	0.05	1	0.10	8	0.16	6	0.12	3	0.08
GREEN	0	ERR	0	ERR	0	ERR	2	0.20	0	ERR	0	ERR	0	ERR
YELLOW	8	0.08	12	0.08	10	0.10	7	0.17	9	0.13	3	0.12	7	0.09
TOTALS	12		14		13		12		17		9		10	

Table 7A. Results for Sample 34, Retroreflective Red.

OSHA COLOR SAMPLE NO. 34

COLOR NAME	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	9	0	2	0	0	8	12
RED ORANGE	5	1	6	0	0	2	4
ORANGE RED	3	1	0	0	0	1	2
PINK	0	0	0	0	0	0	0
ORANGE	2	12	10	0	0	6	2
GOLD	0	0	0	1	0	0	0
YELLOW	0	0	0	2	0	0	0
YELLOW GREEN	0	0	0	0	0	0	0
TAN	0	0	0	5	0	0	0
OLIVE	0	0	0	7	0	0	0
GREEN	0	0	0	1	0	0	0
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	0	0	0	0	0	1	0
MAGENTA	0	0	0	0	0	0	0
BROWN	1	6	2	1	20	2	0
GRAY	0	0	0	3	0	0	0
BLACK	0	0	0	0	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	0	0	0	1	0	0	0
MEDIUM	12	11	16	14	2	12	16
LOW	8	9	4	5	18	8	4
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	8	4	4	0	0	4	10
MEDIUM	12	12	11	7	9	10	9
LOW	0	4	5	11	11	6	1
TOTALS	20	20	20	18	20	20	20

PRIMARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	20	0.81	17	0.66	20	0.74	1	0.95	18	0.83	20	0.80	20	0.87
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	4	0.81	0	ERR	0	ERR	0	ERR
YELLOW	0	ERR	3	0.63	0	ERR	12	0.82	2	0.75	0	ERR	0	ERR
TOTALS	20		20		20		17		20		20		20	

SECONDARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	0	ERR	3	0.37	0	ERR	2	0.20	2	0.25	0	ERR	0	ERR
BLUE	3	0.07	0	ERR	0	ERR	0	ERR	0	ERR	3	0.12	1	0.05
GREEN	0	ERR	0	ERR	0	ERR	10	0.17	2	0.20	0	ERR	0	ERR
YELLOW	17	0.21	17	0.34	20	0.26	5	0.16	15	0.18	16	0.23	17	0.15
TOTALS	20		20		20		17		19		19		18	

Table 8A. Results for Sample 45, Fluorescent Red.

OSHA COLOR SAMPLE NO. 45

COLOR NAME	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	7	4	8	2	10	11	9
RED ORANGE	1	7	3	3	1	0	3
ORANGE RED	1	0	1	3	0	1	0
PINK	9	2	7	0	7	7	4
ORANGE	2	7	3	12	0	0	8
GOLD	0	0	0	0	0	0	0
YELLOW	0	0	0	0	0	0	0
YELLOW GREEN	0	0	0	0	0	0	0
TAN	0	0	0	0	0	0	0
OLIVE	0	0	0	0	0	0	0
GREEN	0	0	0	0	0	0	0
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	0	0	1	0	0	0	0
MAGENTA	0	0	2	0	2	1	1
BROWN	0	0	0	0	0	0	0
GRAY	0	0	0	0	0	0	0
BLACK	0	0	0	0	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	2	3	4	4	2	10	6
MEDIUM	18	17	16	16	18	10	14
LOW	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	13	13	10	12	13	16	14
MEDIUM	7	6	10	8	7	3	6
LOW	0	1	0	0	0	1	0
TOTALS	20	20	20	20	20	20	20

PRIMARY HUES	CW FREQ	CW AVG%	HPS FREQ	HPS AVG%	HPSMH FREQ	HPSMH AVG%	LPS FREQ	LPS AVG%	MER FREQ	MER AVG%	MH FREQ	MH AVG%	TUN FREQ	TUN AVG%
RED	19	0.88	18	0.77	20	0.88	19	0.67	20	0.92	20	0.88	20	0.86
BLUE	1	0.70	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
YELLOW	0	ERR	2	0.55	0	ERR	1	0.60	0	ERR	0	ERR	0	ERR
TOTALS	20		20		20		20		20		20		20	

SECONDARY HUES	CW FREQ	CW AVG%	HPS FREQ	HPS AVG%	HPSMH FREQ	HPSMH AVG%	LPS FREQ	LPS AVG%	MER FREQ	MER AVG%	MH FREQ	MH AVG%	TUN FREQ	TUN AVG%
RED	1	0.30	2	0.45	0	ERR	1	0.40	0	ERR	0	ERR	0	ERR
BLUE	5	0.15	1	0.10	7	0.14	0	ERR	13	0.10	9	0.16	2	0.10
GREEN	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
YELLOW	10	0.16	15	0.26	11	0.13	19	0.33	2	0.13	8	0.13	17	0.15
TOTALS	16		18		18		20		15		17		19	

Table 9A. Results for Sample 47, Fluorescent Red Orange.

OSHA COLOR SAMPLE NO. 47

COLOR NAME	CW	HPS	HPSMH	LPS	MER	MH	TUN
	FREQUENCY						
RED	2	1	3	0	6	3	0
RED ORANGE	7	3	6	3	6	5	5
ORANGE RED	1	0	0	0	0	1	0
PINK	0	0	0	0	0	0	0
ORANGE	10	16	11	17	8	11	15
GOLD	0	0	0	0	0	0	0
YELLOW	0	0	0	0	0	0	0
YELLOW GREEN	0	0	0	0	0	0	0
TAN	0	0	0	0	0	0	0
OLIVE	0	0	0	0	0	0	0
GREEN	0	0	0	0	0	0	0
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	0	0	0	0	0	0	0
MAGENTA	0	0	0	0	0	0	0
BROWN	0	0	0	0	0	0	0
GRAY	0	0	0	0	0	0	0
BLACK	0	0	0	0	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	CW	HPS	HPSMH	LPS	MER	MH	TUN
	FREQUENCY						
HIGH	5	2	6	3	4	4	6
MEDIUM	15	18	14	17	16	16	14
LOW	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

SATURATION	CW	HPS	HPSMH	LPS	MER	MH	TUN
	FREQUENCY						
HIGH	19	13	16	5	17	18	15
MEDIUM	1	7	4	14	3	2	5
LOW	0	0	0	1	0	0	0
TOTALS	20	20	20	20	20	20	20

PRIMARY HUES	CW FREQ	CW AVG%	HPS FREQ	HPS AVG%	HPSMH FREQ	HPSMH AVG%	LPS FREQ	LPS AVG%	MER FREQ	MER AVG%	MH FREQ	MH AVG%	TUN FREQ	TUN AVG%
RED	20	0.67	17	0.61	19	0.69	17	0.62	20	0.72	20	0.68	18	0.64
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
YELLOW	0	ERR	3	0.57	1	0.50	3	0.63	0	ERR	0	ERR	2	0.60
TOTALS	20		20		20		20		20		20		20	

SECONDARY HUES	CW FREQ	CW AVG%	HPS FREQ	HPS AVG%	HPSMH FREQ	HPSMH AVG%	LPS FREQ	LPS AVG%	MER FREQ	MER AVG%	MH FREQ	MH AVG%	TUN FREQ	TUN AVG%
RED	0	ERR	3	0.43	1	0.50	3	0.37	0	ERR	0	ERR	2	0.40
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
YELLOW	20	0.33	17	0.39	19	0.31	17	0.38	20	0.28	20	0.32	18	0.36
TOTALS	20		20		20		20		20		20		20	

Table 10A. Results for Sample 57, Fluorescent Red.

OSHA COLOR SAMPLE NO. 57

COLOR NAME	CW	HPS	HPSMH	LPS	MER	MH	TUN
	FREQUENCY						
RED	17	17	15	8	18	19	17
RED ORANGE	0	1	2	0	0	0	1
ORANGE RED	0	1	1	1	0	1	2
PINK	0	0	0	0	0	0	0
ORANGE	0	0	0	1	0	0	0
GOLD	0	0	0	0	0	0	0
YELLOW	0	0	0	0	0	0	0
YELLOW GREEN	0	0	0	0	0	0	0
TAN	0	0	0	0	0	0	0
OLIVE	0	0	0	0	0	0	0
GREEN	0	0	0	0	0	0	0
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	2	0	0	2	0	0	0
MAGENTA	1	0	2	1	1	0	0
BROWN	0	1	0	7	1	0	0
GRAY	0	0	0	0	0	0	0
BLACK	0	0	0	0	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	CW	HPS	HPSMH	LPS	MER	MH	TUN
	FREQUENCY						
HIGH	0	0	0	0	0	0	0
MEDIUM	13	8	11	11	11	12	16
LOW	7	12	9	9	9	8	4
TOTALS	20	20	20	20	20	20	20

SATURATION	CW	HPS	HPSMH	LPS	MER	MH	TUN
	FREQUENCY						
HIGH	4	2	4	0	3	4	12
MEDIUM	13	14	13	9	13	14	3
LOW	3	4	3	11	4	2	5
TOTALS	20	20	20	20	20	20	20

PRIMARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	20	0.90	20	0.90	20	0.93	20	0.92	20	0.93	20	0.91	20	0.94
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
YELLOW	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
TOTALS	20		20		20		20		20		20		20	

SECONDARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
BLUE	10	0.12	5	0.11	8	0.10	4	0.09	10	0.09	8	0.13	5	0.06
GREEN	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
YELLOW	6	0.15	10	0.14	4	0.16	13	0.10	6	0.11	6	0.13	7	0.13
TOTALS	16		15		12		17		16		14		12	

Table 11A. Results for Sample 58, Fluorescent Red.

OSHA COLOR SAMPLE NO. 58

COLOR NAME	CW	HPS	HPSMH	LPS	MER	MH	TUN
	FREQUENCY						
RED	14	14	13	7	15	13	20
RED ORANGE	0	0	0	0	0	0	0
ORANGE RED	1	0	0	0	0	0	0
PINK	0	0	0	0	0	0	0
ORANGE	0	0	0	2	0	0	0
GOLD	0	0	0	0	0	0	0
YELLOW	0	0	0	0	0	0	0
YELLOW GREEN	0	0	0	0	0	0	0
TAN	0	0	0	0	0	0	0
OLIVE	0	0	0	0	0	0	0
GREEN	0	0	0	0	0	0	0
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	2	2	2	2	2	2	0
MAGENTA	2	2	2	0	2	3	0
BROWN	1	2	3	9	1	1	0
GRAY	0	0	0	0	0	0	0
BLACK	0	0	0	0	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	19	20

LIGHTNESS	CW	HPS	HPSMH	LPS	MER	MH	TUN
	FREQUENCY						
HIGH	0	0	1	0	0	1	0
MEDIUM	11	8	11	12	9	11	15
LOW	9	12	8	8	11	8	5
TOTALS	20	20	20	20	20	20	20

SATURATION	CW	HPS	HPSMH	LPS	MER	MH	TUN
	FREQUENCY						
HIGH	4	2	4	0	3	4	9
MEDIUM	13	15	12	10	14	12	7
LOW	3	3	4	10	3	4	4
TOTALS	20	20	20	20	20	20	20

PRIMARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	20	0.90	19	0.92	20	0.91	20	0.85	20	0.90	20	0.88	20	0.94
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
YELLOW	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
TOTALS	20		19		20		20		20		20		20	

SECONDARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
BLUE	11	0.13	8	0.15	11	0.12	4	0.13	11	0.16	14	0.13	6	0.09
GREEN	0	ERR	1	0.30	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
YELLOW	4	0.14	5	0.09	5	0.09	15	0.17	3	0.07	3	0.22	6	0.12
TOTALS	15		14		16		19		14		17		12	

Table 12A. Results for Sample 5, ANSI Orange.

OSHA COLOR SAMPLE NO. 5

COLOR NAME	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	0	0	0	0	0	0	0
RED ORANGE	0	0	0	0	0	0	0
ORANGE RED	0	0	0	0	0	0	0
PINK	0	0	0	0	0	0	0
ORANGE	13	5	10	0	0	11	17
GOLD	5	2	5	0	3	5	1
YELLOW	0	13	2	20	12	1	1
YELLOW GREEN	0	0	1	0	1	0	0
TAN	2	0	2	0	2	0	1
OLIVE	0	0	0	0	1	0	0
GREEN	0	0	0	0	1	0	0
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	0	0	0	0	0	0	0
MAGENTA	0	0	0	0	0	0	0
BROWN	0	0	0	0	0	3	0
GRAY	0	0	0	0	0	0	0
BLACK	0	0	0	0	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	2	6	1	9	1	2	3
MEDIUM	18	13	19	11	17	17	16
LOW	0	1	0	0	2	1	1
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	1	10	5	10	1	3	3
MEDIUM	19	10	13	6	12	13	15
LOW	0	0	2	4	7	4	2
TOTALS	20	20	20	20	20	20	20

PRIMARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	3	0.57	1	0.50	2	0.55	0	ERR	0	ERR	2	0.55	6	0.58
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	0	ERR	1	0.80	0	ERR	0	ERR
YELLOW	17	0.72	19	0.88	18	0.82	20	0.96	19	0.93	18	0.74	14	0.76
TOTALS	20		20		20		20		20		20		20	

SECONDARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	17	0.28	14	0.16	15	0.21	9	0.06	5	0.09	17	0.28	14	0.24
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	2	0.08	3	0.07	7	0.13	0	ERR	0	ERR
YELLOW	3	0.43	1	0.50	2	0.45	0	ERR	1	0.20	2	0.45	6	0.43
TOTALS	20		15		19		12		13		19		20	

Table 13A. Results for Sample 15, Retroreflective-Fluorescent Orange.

OSHA COLOR SAMPLE NO. 15

COLOR NAME	CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	0	0	0	0	0	0	0
RED ORANGE	0	0	0	0	0	1	1
ORANGE RED	0	0	0	0	0	0	0
PINK	0	0	0	0	0	0	0
ORANGE	20	19	20	17	20	19	19
GOLD	0	0	0	0	0	0	0
YELLOW	0	1	0	2	0	0	0
YELLOW GREEN	0	0	0	0	0	0	0
TAN	0	0	0	0	0	0	0
OLIVE	0	0	0	1	0	0	0
GREEN	0	0	0	0	0	0	0
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	0	0	0	0	0	0	0
MAGENTA	0	0	0	0	0	0	0
BROWN	0	0	0	0	0	0	0
GRAY	0	0	0	0	0	0	0
BLACK	0	0	0	0	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

(FREQUENCY)

LIGHTNESS	CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	8	6	4	5	7	6	3
MEDIUM	12	12	16	15	13	14	17
LOW	0	2	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

(FREQUENCY)

SATURATION	CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	18	8	14	3	19	17	12
MEDIUM	2	12	6	14	1	3	8
LOW	0	0	0	3	0	0	0
TOTALS	20	20	20	20	20	20	20

(FREQUENCY)

PRIMARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	12	0.54	6	0.53	7	0.56	4	0.53	10	0.54	9	0.60	7	0.57
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
YELLOW	8	0.70	14	0.66	13	0.68	16	0.67	10	0.62	11	0.62	13	0.63
TOTALS	20		20		20		20		20		20		20	

SECONDARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	8	0.30	14	0.34	13	0.32	15	0.29	10	0.38	11	0.38	13	0.37
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	1	1.00	0	ERR	0	ERR	0	ERR
YELLOW	12	0.46	6	0.48	7	0.44	4	0.48	10	0.46	9	0.40	7	0.43
TOTALS	20		20		20		20		20		20		20	

Table 14A. Results for Sample 16, Fluorescent Orange.

OSHA COLOR SAMPLE NO. 16

COLOR NAME	FREQUENCY						
	CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	0	0	0	0	0	0	0
RED ORANGE	0	0	0	0	0	0	0
ORANGE RED	0	0	0	0	0	0	0
PINK	0	0	0	0	0	0	0
ORANGE	20	20	20	1	19	20	20
GOLD	0	0	0	0	0	0	0
YELLOW	0	0	0	19	1	0	0
YELLOW GREEN	0	0	0	0	0	0	0
TAN	0	0	0	0	0	0	0
OLIVE	0	0	0	0	0	0	0
GREEN	0	0	0	0	0	0	0
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	0	0	0	0	0	0	0
MAGENTA	0	0	0	0	0	0	0
BROWN	0	0	0	0	0	0	0
GRAY	0	0	0	0	0	0	0
BLACK	0	0	0	0	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY						
	CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	6	9	11	9	8	11	6
MEDIUM	14	11	9	11	12	9	14
LOW	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY						
	CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	17	15	8	14	10	14	9
MEDIUM	3	5	11	6	10	6	11
LOW	0	0	1	0	0	0	0
TOTALS	20	20	20	20	20	20	20

PRIMARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	7	0.60	2	0.55	5	0.57	0	ERR	6	0.55	9	0.52	3	0.53
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
YELLOW	13	0.63	18	0.63	15	0.65	20	0.94	14	0.66	11	0.68	17	0.62
TOTALS	20		20		20		20		20		20		20	

SECONDARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	13	0.37	18	0.37	15	0.35	12	0.09	14	0.34	11	0.32	17	0.38
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	4	0.05	0	ERR	0	ERR	0	ERR
YELLOW	7	0.40	2	0.45	5	0.40	0	ERR	6	0.45	9	0.48	3	0.47
TOTALS	20		20		20		16		20		20		20	

Table 15A. Results for Sample 17, Retroreflective-Fluorescent Orange.

OSHA COLOR SAMPLE NO. 17

COLOR NAME	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	0	0	0	0	0	0	0
RED ORANGE	0	0	0	0	0	0	2
ORANGE RED	1	0	0	0	0	0	0
PINK	0	0	0	0	0	0	0
ORANGE	14	13	12	0	1	13	16
GOLD	1	0	5	3	3	0	0
YELLOW	0	1	0	6	2	0	0
YELLOW GREEN	0	0	0	1	0	0	0
TAN	0	2	2	4	3	0	0
OLIVE	0	0	0	5	3	0	0
GREEN	0	0	0	0	1	0	0
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	0	0	0	0	0	0	0
MAGENTA	0	0	0	0	0	0	0
BROWN	4	4	1	0	7	7	2
GRAY	0	0	0	1	0	0	0
BLACK	0	0	0	0	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	1	3	1	2	1	0	0
MEDIUM	11	14	15	17	10	14	19
LOW	8	3	4	1	9	6	1
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	2	1	2	2	0	2	5
MEDIUM	16	16	13	7	11	13	11
LOW	2	3	5	11	9	5	4
TOTALS	20	20	20	20	20	20	20

PRIMARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	10	0.76	7	0.63	10	0.63	0	ERR	2	0.88	10	0.68	17	0.64
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	1	0.70	3	0.83	0	ERR	0	ERR
YELLOW	10	0.67	13	0.67	10	0.70	18	0.90	15	0.82	10	0.64	3	0.58
TOTALS	20		20		20		19		20		20		20	

SECONDARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	10	0.33	13	0.33	10	0.31	2	0.05	7	0.18	10	0.36	3	0.42
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	14	0.12	7	0.21	1	0.40	0	ERR
YELLOW	10	0.24	7	0.37	10	0.37	2	0.20	5	0.15	9	0.31	17	0.36
TOTALS	20		20		20		18		19		20		20	

Table 16A. Results for Sample 18, Fluorescent Orange.

OSHA COLOR SAMPLE NO. 18

COLOR NAME	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	0	0	0	0	0	0	0
RED ORANGE	0	0	0	0	0	0	0
ORANGE RED	0	0	0	0	0	0	0
PINK	0	0	0	0	0	0	0
ORANGE	13	17	13	0	3	18	19
GOLD	2	0	3	0	5	0	1
YELLOW	3	3	3	20	12	1	0
YELLOW GREEN	0	0	0	0	0	0	0
TAN	2	0	1	0	0	0	0
OLIVE	0	0	0	0	0	0	0
GREEN	0	0	0	0	0	0	0
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	0	0	0	0	0	0	0
MAGENTA	0	0	0	0	0	0	0
BROWN	0	0	0	0	0	1	0
GRAY	0	0	0	0	0	0	0
BLACK	0	0	0	0	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	4	8	3	15	1	3	4
MEDIUM	16	12	17	5	18	17	15
LOW	0	0	0	0	1	0	1
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	7	10	6	15	3	10	8
MEDIUM	13	10	14	5	15	10	11
LOW	0	0	0	0	2	0	1
TOTALS	20	20	20	20	20	20	20

PRIMARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	1	0.50	3	0.62	2	0.65	0	ERR	0	ERR	1	0.60	3	0.57
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
YELLOW	19	0.76	17	0.75	18	0.79	20	0.97	20	0.91	19	0.70	17	0.69
TOTALS	20		20		20		20		20		20		20	

SECONDARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	17	0.25	15	0.28	17	0.22	7	0.07	9	0.13	19	0.30	17	0.31
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	1	0.20	0	ERR	0	ERR	2	0.05	5	0.11	0	ERR	0	ERR
YELLOW	1	0.50	3	0.38	2	0.35	0	ERR	0	ERR	1	0.40	3	0.43
TOTALS	19		18		19		9		14		20		20	

Table 17A. Results for Sample 35, Retroreflective-Fluorescent Orange.

OSHA COLOR SAMPLE NO. 35

COLOR NAME	FREQUENCY						
	CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	0	0	0	0	0	0	0
RED ORANGE	0	0	0	0	0	0	0
ORANGE RED	0	0	0	0	0	0	0
PINK	0	0	0	0	0	0	0
ORANGE	13	16	12	0	1	16	19
GOLD	1	1	5	0	3	0	0
YELLOW	1	0	1	19	6	1	0
YELLOW GREEN	0	0	0	0	0	0	0
TAN	2	3	2	0	2	0	0
OLIVE	0	0	0	1	7	0	0
GREEN	0	0	0	0	1	0	0
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	0	0	0	0	0	0	0
MAGENTA	0	0	0	0	0	0	0
BROWN	3	0	0	0	0	3	1
GRAY	0	0	0	0	0	0	0
BLACK	0	0	0	0	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY						
	CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	2	3	1	7	0	1	1
MEDIUM	16	17	16	12	15	16	17
LOW	2	0	3	1	5	3	2
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY						
	CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	0	4	3	7	0	1	4
MEDIUM	16	15	13	7	7	14	12
LOW	4	1	4	6	13	5	4
TOTALS	20	20	20	20	20	20	20

PRIMARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	6	0.67	5	0.54	6	0.57	0	ERR	0	ERR	8	0.61	13	0.61
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	0	ERR	4	0.85	0	ERR	0	ERR
YELLOW	14	0.70	15	0.69	14	0.78	20	0.96	16	0.84	12	0.78	7	0.64
TOTALS	20		20		20		20		20		20		20	

SECONDARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	13	0.31	15	0.31	14	0.22	3	0.07	5	0.13	11	0.24	7	0.36
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	1	0.10	0	ERR	0	ERR
GREEN	1	0.20	0	ERR	0	ERR	5	0.11	10	0.18	1	0.10	0	ERR
YELLOW	6	0.33	5	0.46	6	0.43	0	ERR	4	0.15	8	0.39	13	0.39
TOTALS	20		20		20		8		20		20		20	

Table 18A. Results for Sample 42, Retroreflective Orange.

OSHA COLOR SAMPLE NO. 42

COLOR NAME	CW	HPS	HPSMH	LPS	MER	MH	TUN
	FREQUENCY						
RED	0	0	0	0	0	0	0
RED ORANGE	1	0	2	0	2	0	0
ORANGE RED	0	0	0	0	1	0	0
PINK	0	0	0	0	0	0	0
ORANGE	19	18	18	18	17	20	20
GOLD	0	1	0	0	0	0	0
YELLOW	0	1	0	0	0	0	0
YELLOW GREEN	0	0	0	0	0	0	0
TAN	0	0	0	1	0	0	0
OLIVE	0	0	0	1	0	0	0
GREEN	0	0	0	0	0	0	0
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	0	0	0	0	0	0	0
MAGENTA	0	0	0	0	0	0	0
BROWN	0	0	0	0	0	0	0
GRAY	0	0	0	0	0	0	0
BLACK	0	0	0	0	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	CW	HPS	HPSMH	LPS	MER	MH	TUN
	FREQUENCY						
HIGH	3	2	1	6	1	4	0
MEDIUM	17	18	19	12	19	16	20
LOW	0	0	0	2	0	0	0
TOTALS	20	20	20	20	20	20	20

SATURATION	CW	HPS	HPSMH	LPS	MER	MH	TUN
	FREQUENCY						
HIGH	17	10	12	3	11	15	11
MEDIUM	3	9	8	9	9	5	9
LOW	0	1	0	8	0	0	0
TOTALS	20	20	20	20	20	20	20

PRIMARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	14	0.61	9	0.58	13	0.57	4	0.55	15	0.59	17	0.55	13	0.57
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
YELLOW	6	0.63	11	0.62	7	0.65	16	0.69	5	0.63	3	0.60	7	0.60
TOTALS	20		20		20		20		20		20		20	

SECONDARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	6	0.38	11	0.38	7	0.35	15	0.32	5	0.37	3	0.40	7	0.40
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	1	0.10	0	ERR	0	ERR	0	ERR
YELLOW	14	0.39	9	0.42	13	0.43	4	0.45	15	0.41	17	0.45	13	0.43
TOTALS	20		20		20		20		20		20		20	

Table 19A. Results for Sample 46, Ordinary Orange.

OSHA COLOR SAMPLE NO. 46

COLOR NAME	CW	HPS	HPSMH	LPS	MER	MH	TUN
	FREQUENCY						
RED	5	1	5	1	9	7	5
RED ORANGE	5	3	4	3	4	6	6
ORANGE RED	2	1	1	0	0	3	1
PINK	2	0	1	0	3	0	0
ORANGE	6	15	9	16	4	4	8
GOLD	0	0	0	0	0	0	0
YELLOW	0	0	0	0	0	0	0
YELLOW GREEN	0	0	0	0	0	0	0
TAN	0	0	0	0	0	0	0
OLIVE	0	0	0	0	0	0	0
GREEN	0	0	0	0	0	0	0
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	0	0	0	0	0	0	0
MAGENTA	0	0	0	0	0	0	0
BROWN	0	0	0	0	0	0	0
GRAY	0	0	0	0	0	0	0
BLACK	0	0	0	0	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	CW	HPS	HPSMH	LPS	MER	MH	TUN
	FREQUENCY						
HIGH	2	3	3	3	1	3	5
MEDIUM	18	17	17	17	19	17	15
LOW	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

SATURATION	CW	HPS	HPSMH	LPS	MER	MH	TUN
	FREQUENCY						
HIGH	15	15	14	8	17	19	17
MEDIUM	5	5	6	12	3	1	3
LOW	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

PRIMARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	19	0.79	19	0.66	20	0.77	18	0.64	20	0.84	20	0.77	19	0.75
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
YELLOW	1	0.60	1	0.50	0	ERR	2	0.60	0	ERR	0	ERR	1	0.60
TOTALS	20		20		20		20		20		20		20	

SECONDARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	1	0.40	1	0.50	0	ERR	2	0.40	0	ERR	0	ERR	1	0.40
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	4	0.09	1	0.20	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
YELLOW	18	0.23	19	0.34	19	0.24	18	0.36	16	0.18	19	0.23	18	0.27
TOTALS	19		20		19		20		20		20		19	

Table 20A. Results for Sample 48, Retroreflective Orange.

OSHA COLOR SAMPLE NO. 48

COLOR NAME	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	1	0	0	0	0	0	0
RED ORANGE	1	0	2	0	0	0	1
ORANGE RED	0	0	0	0	0	0	0
PINK	0	0	0	0	0	0	0
ORANGE	18	20	18	20	20	20	19
GOLD	0	0	0	0	0	0	0
YELLOW	0	0	0	0	0	0	0
YELLOW GREEN	0	0	0	0	0	0	0
TAN	0	0	0	0	0	0	0
OLIVE	0	0	0	0	0	0	0
GREEN	0	0	0	0	0	0	0
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	0	0	0	0	0	0	0
MAGENTA	0	0	0	0	0	0	0
BROWN	0	0	0	0	0	0	0
GRAY	0	0	0	0	0	0	0
BLACK	0	0	0	0	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	9	8	5	12	5	7	4
MEDIUM	11	12	15	8	15	13	16
LOW	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	16	16	13	8	18	15	16
MEDIUM	4	4	7	12	2	5	4
LOW	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

PRIMARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	15	0.60	11	0.60	13	0.60	2	0.55	17	0.58	15	0.55	12	0.58
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
YELLOW	5	0.57	9	0.61	7	0.65	18	0.69	3	0.57	5	0.62	8	0.64
TOTALS	20		20		20		20		20		20		20	

SECONDARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	5	0.43	9	0.39	7	0.35	18	0.31	3	0.43	5	0.38	8	0.36
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
YELLOW	15	0.40	11	0.40	13	0.40	2	0.45	17	0.42	15	0.45	12	0.42
TOTALS	20		20		20		20		20		20		20	

Table 21A. Results for Sample 56, Retroreflective Orange Red.

OSHA COLOR SAMPLE NO. 56

COLOR NAME	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	0	0	0	0	0	0	0
RED ORANGE	0	1	0	0	0	1	0
ORANGE RED	0	0	0	0	0	0	0
PINK	0	0	0	0	0	0	0
ORANGE	19	18	20	13	20	19	20
GOLD	1	1	0	2	0	0	0
YELLOW	0	0	0	2	0	0	0
YELLOW GREEN	0	0	0	0	0	0	0
TAN	0	0	0	2	0	0	0
OLIVE	0	0	0	0	0	0	0
GREEN	0	0	0	0	0	0	0
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	0	0	0	0	0	0	0
MAGENTA	0	0	0	0	0	0	0
BROWN	0	0	0	1	0	0	0
GRAY	0	0	0	0	0	0	0
BLACK	0	0	0	0	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	3	4	1	5	1	3	1
MEDIUM	17	15	19	13	19	17	19
LOW	0	1	0	2	0	0	0
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	13	3	12	2	15	18	6
MEDIUM	7	17	8	7	5	2	14
LOW	0	0	0	11	0	0	0
TOTALS	20	20	20	20	20	20	20

PRIMARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	10	0.57	12	0.54	9	0.55	4	0.60	7	0.59	12	0.55	8	0.55
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
YELLOW	10	0.68	8	0.73	11	0.69	16	0.77	13	0.60	8	0.63	12	0.65
TOTALS	20		20		20		20		20		20		20	

SECONDARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	10	0.32	8	0.28	11	0.31	15	0.24	13	0.40	8	0.38	12	0.35
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	1	0.10	0	ERR	0	ERR	0	ERR
YELLOW	10	0.44	12	0.46	9	0.45	4	0.40	7	0.41	12	0.45	8	0.45
TOTALS	20		20		20		20		20		20		20	

OSHA COLOR SAMPLE NO. 4

COLOR NAME	CW	HPS	HPSMH	LPS	MER	MH	TUN
	FREQUENCY						
RED	0	0	0	0	0	0	0
RED ORANGE	0	0	0	0	0	0	0
ORANGE RED	0	0	0	0	0	0	0
PINK	0	0	0	0	0	0	0
ORANGE	0	0	0	0	0	0	1
GOLD	0	0	1	0	0	0	0
YELLOW	15	19	17	20	8	16	17
YELLOW GREEN	4	1	2	0	10	4	2
TAN	0	0	0	0	0	0	0
OLIVE	1	0	0	0	0	0	0
GREEN	0	0	0	0	2	0	0
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	0	0	0	0	0	0	0
MAGENTA	0	0	0	0	0	0	0
BROWN	0	0	0	0	0	0	0
GRAY	0	0	0	0	0	0	0
BLACK	0	0	0	0	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	CW	HPS	HPSMH	LPS	MER	MH	TUN
	FREQUENCY						
HIGH	12	14	12	14	11	11	9
MEDIUM	8	6	8	6	9	9	11
LOW	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

SATURATION	CW	HPS	HPSMH	LPS	MER	MH	TUN
	FREQUENCY						
HIGH	6	11	6	18	10	12	5
MEDIUM	14	7	14	2	9	8	14
LOW	0	2	0	0	1	0	1
TOTALS	20	20	20	20	20	20	20

PRIMARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	1	0.60	0	ERR	3	0.80	2	0.75	0	ERR
YELLOW	20	0.90	20	0.93	19	0.94	20	0.99	17	0.85	18	0.95	20	0.94
TOTALS	20		20		20		20		20		20		20	

SECONDARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	1	0.10	2	0.10	0	ERR	1	0.10	0	ERR	0	ERR	1	0.30
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	15	0.13	10	0.12	10	0.12	3	0.07	14	0.18	8	0.12	11	0.08
YELLOW	0	ERR	0	ERR	1	0.40	0	ERR	3	0.20	2	0.25	0	ERR
TOTALS	16		12		11		4		17		10		12	

Table 23A. Results for Sample 19, Retroreflective-Fluorescent Yellow.

OSHA COLOR SAMPLE NO. 19

COLOR NAME	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	0	0	0	0	0	0	0
RED ORANGE	0	0	0	0	0	0	0
ORANGE RED	0	0	0	0	0	0	0
PINK	0	0	0	0	0	0	0
ORANGE	0	0	0	0	0	0	0
GOLD	0	0	0	1	0	0	0
YELLOW	6	10	6	14	5	3	4
YELLOW GREEN	14	9	14	1	12	14	12
TAN	0	0	0	0	0	0	0
OLIVE	0	0	0	4	0	0	0
GREEN	0	1	0	0	3	3	4
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	0	0	0	0	0	0	0
MAGENTA	0	0	0	0	0	0	0
BROWN	0	0	0	0	0	0	0
GRAY	0	0	0	0	0	0	0
BLACK	0	0	0	0	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	14	12	14	7	11	14	14
MEDIUM	6	8	6	13	9	6	6
LOW	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	14	11	6	7	11	13	7
MEDIUM	6	8	14	12	9	7	11
LOW	0	1	0	1	0	0	2
TOTALS	20	20	20	20	20	20	20

PRIMARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	4	0.61	2	0.68	5	0.64	0	ERR	6	0.70	6	0.67	8	0.71
YELLOW	16	0.81	18	0.86	15	0.78	20	0.95	14	0.81	14	0.71	12	0.79
TOTALS	20		20		20		20		20		20		20	

SECONDARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	0	ERR	0	ERR	0	ERR	2	0.08	0	ERR	0	ERR	0	ERR
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	16	0.19	16	0.16	15	0.22	7	0.14	14	0.19	13	0.31	11	0.23
YELLOW	4	0.39	2	0.33	5	0.36	0	ERR	6	0.30	6	0.33	8	0.29
TOTALS	20		18		20		9		20		19		19	

Table 24A. Results for Sample 20, Fluorescent Yellow.

OSHA COLOR SAMPLE NO. 20

COLOR NAME	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	0	0	0	0	0	0	0
RED ORANGE	0	0	0	0	0	0	0
ORANGE RED	0	0	0	0	0	0	0
PINK	0	0	0	0	0	0	0
ORANGE	0	0	1	0	0	0	0
GOLD	0	0	0	0	0	0	0
YELLOW	8	18	11	20	8	11	14
YELLOW GREEN	12	2	8	0	12	9	5
TAN	0	0	0	0	0	0	0
OLIVE	0	0	0	0	0	0	0
GREEN	0	0	0	0	0	0	1
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	0	0	0	0	0	0	0
MAGENTA	0	0	0	0	0	0	0
BROWN	0	0	0	0	0	0	0
GRAY	0	0	0	0	0	0	0
BLACK	0	0	0	0	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	18	15	18	15	15	13	15
MEDIUM	2	5	2	5	5	7	5
LOW	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	15	13	14	18	14	15	11
MEDIUM	5	6	6	2	5	5	8
LOW	0	1	0	0	1	0	1
TOTALS	20	20	20	20	20	20	20

PRIMARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	0	ERR	0	ERR	1	0.50	0	ERR	0	ERR	0	ERR	0	ERR
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	1	0.60	0	ERR	1	0.80	0	ERR	2	0.65	0	ERR	2	0.60
YELLOW	19	0.83	20	0.93	18	0.84	20	0.97	18	0.81	20	0.85	18	0.90
TOTALS	20		20		20		20		20		20		20	

SECONDARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	0	ERR	0	ERR	2	0.10	2	0.08	0	ERR	0	ERR	0	ERR
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	18	0.18	12	0.12	15	0.18	3	0.15	18	0.19	16	0.19	13	0.14
YELLOW	1	0.40	0	ERR	2	0.35	0	ERR	2	0.35	0	ERR	2	0.40
TOTALS	19		12		19		5		20		16		15	

Table 25A. Results for Sample 21, Retroreflective Yellow.

OSHA COLOR SAMPLE NO. 21

COLOR NAME	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	0	0	0	0	0	0	0
RED ORANGE	0	0	0	0	0	0	0
ORANGE RED	0	0	0	0	0	0	0
PINK	0	0	0	0	0	0	0
ORANGE	3	1	5	0	0	7	6
GOLD	3	0	2	1	3	6	6
YELLOW	11	18	10	19	13	5	6
YELLOW GREEN	1	1	0	0	3	1	1
TAN	1	0	0	0	0	1	1
OLIVE	1	0	3	0	1	0	0
GREEN	0	0	0	0	0	0	0
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	0	0	0	0	0	0	0
MAGENTA	0	0	0	0	0	0	0
BROWN	0	0	0	0	0	0	0
GRAY	0	0	0	0	0	0	0
BLACK	0	0	0	0	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	4	7	5	8	1	4	5
MEDIUM	16	13	15	12	19	14	14
LOW	0	0	0	0	0	2	1
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	3	8	6	9	2	2	3
MEDIUM	14	10	13	9	16	14	13
LOW	3	2	1	2	2	4	4
TOTALS	20	20	20	20	20	20	20

PRIMARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	1	0.50	0	ERR	0	ERR	0	ERR	0	ERR	3	0.62	0	ERR
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	1	0.70	0	ERR	1	0.80	0	ERR	0	ERR
YELLOW	19	0.94	20	0.95	19	0.88	20	0.97	19	0.96	17	0.85	20	0.85
TOTALS	20		20		20		20		20		20		20	

SECONDARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	8	0.08	3	0.12	12	0.17	3	0.05	2	0.05	9	0.22	13	0.20
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	6	0.09	5	0.12	3	0.08	5	0.09	10	0.08	6	0.10	2	0.15
YELLOW	1	0.50	0	ERR	1	0.50	0	ERR	1	0.20	3	0.38	0	ERR
TOTALS	15		8		16		8		13		18		15	

Table 26A. Results for Sample 22, Ordinary Yellow.

OSHA COLOR SAMPLE NO. 22

COLOR NAME	FREQUENCY						
	CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	0	0	0	0	0	0	0
RED ORANGE	0	0	0	0	0	0	0
ORANGE RED	0	0	0	0	0	0	0
PINK	0	0	0	0	0	0	0
ORANGE	3	1	2	0	0	2	3
GOLD	0	0	0	0	0	1	0
YELLOW	16	19	18	20	13	17	17
YELLOW GREEN	0	0	0	0	7	0	0
TAN	0	0	0	0	0	0	0
OLIVE	1	0	0	0	0	0	0
GREEN	0	0	0	0	0	0	0
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	0	0	0	0	0	0	0
MAGENTA	0	0	0	0	0	0	0
BROWN	0	0	0	0	0	0	0
GRAY	0	0	0	0	0	0	0
BLACK	0	0	0	0	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY						
	CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	15	13	10	13	10	11	13
MEDIUM	5	7	10	7	10	9	7
LOW	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY						
	CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	12	12	9	18	10	11	10
MEDIUM	7	7	10	2	9	9	9
LOW	1	1	1	0	1	0	1
TOTALS	20	20	20	20	20	20	20

PRIMARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	0	ERR	1	0.70	0	ERR	0	ERR
YELLOW	20	0.94	19	0.94	20	0.94	20	0.98	19	0.92	20	0.96	20	0.69
TOTALS	20		19		20		20		20		20		20	

SECONDARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	4	0.20	4	0.10	9	0.09	3	0.07	0	ERR	7	0.09	9	0.68
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	4	0.09	7	0.11	7	0.06	2	0.19	12	0.18	2	0.15	1	0.05
YELLOW	0	ERR	0	ERR	0	ERR	0	ERR	1	0.30	0	ERR	0	ERR
TOTALS	8		11		16		5		13		9		10	

Table 27A. Results for Sample 36, Retroreflective Yellow.

OSHA COLOR SAMPLE NO. 36

COLOR NAME	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	0	0	0	0	0	0	0
RED ORANGE	0	0	0	0	0	0	0
ORANGE RED	0	0	0	0	0	0	0
PINK	0	0	0	0	0	0	0
ORANGE	0	2	4	0	0	3	2
GOLD	4	2	3	0	1	2	6
YELLOW	12	15	10	17	9	11	10
YELLOW GREEN	2	0	1	1	7	1	1
TAN	1	0	1	1	0	1	1
OLIVE	1	0	1	1	0	2	0
GREEN	0	1	0	0	3	0	0
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	0	0	0	0	0	0	0
MAGENTA	0	0	0	0	0	0	0
BROWN	0	0	0	0	0	0	0
GRAY	0	0	0	0	0	0	0
BLACK	0	0	0	0	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	5	5	4	8	6	3	4
MEDIUM	14	15	15	12	14	14	14
LOW	1	0	1	0	0	3	2
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	3	7	4	6	4	2	1
MEDIUM	15	11	15	12	13	11	15
LOW	2	2	1	2	3	7	4
TOTALS	20	20	20	20	20	20	20

PRIMARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	1	0.50	0	ERR
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	0	ERR	4	0.75	0	ERR	0	ERR
YELLOW	20	0.91	20	0.89	20	0.65	20	0.96	16	0.85	19	0.88	20	0.88
TOTALS	20		20		20		20		20		20		20	

SECONDARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	4	0.18	4	0.16	10	0.63	3	0.07	0	ERR	7	0.18	11	0.12
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	11	0.10	8	0.19	7	0.11	6	0.09	14	0.18	8	0.13	6	0.17
YELLOW	0	ERR	0	ERR	0	ERR	0	ERR	4	0.25	1	0.50	0	ERR
TOTALS	15		12		17		9		18		16		17	

Table 28A. Results for Sample 37, Retroreflective Yellow.

OSHA COLOR SAMPLE NO. 37

COLOR NAME	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	0	0	0	0	0	0	0
RED ORANGE	0	0	0	0	0	0	0
ORANGE RED	0	0	0	0	0	0	0
PINK	0	0	0	0	0	0	0
ORANGE	0	0	1	0	0	0	0
GOLD	6	3	4	2	2	6	3
YELLOW	4	12	7	15	8	7	6
YELLOW GREEN	0	2	0	1	4	0	0
TAN	7	1	6	0	1	7	9
OLIVE	3	2	2	2	1	0	1
GREEN	0	0	0	0	4	0	1
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	0	0	0	0	0	0	0
MAGENTA	0	0	0	0	0	0	0
BROWN	0	0	0	0	0	0	0
GRAY	0	0	0	0	0	0	0
BLACK	0	0	0	0	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	6	6	6	5	6	6	5
MEDIUM	12	14	12	15	12	9	12
LOW	2	0	2	0	2	5	3
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	0	1	0	6	0	0	0
MEDIUM	10	11	7	10	7	7	4
LOW	10	8	13	4	13	13	16
TOTALS	20	20	20	20	20	20	20

PRIMARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	2	0.70	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	2	0.65	0	ERR	0	ERR	6	0.82	0	ERR	2	0.70
YELLOW	18	0.88	18	0.90	20	0.88	20	0.92	14	0.88	20	0.86	18	0.88
TOTALS	20		20		20		20		20		20		20	

SECONDARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	3	0.12	6	0.14	6	0.18	4	0.11	0	ERR	6	0.18	6	0.14
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	12	0.15	10	0.09	9	0.14	10	0.13	13	0.13	13	0.13	8	0.16
YELLOW	2	0.30	2	0.35	0	ERR	0	ERR	5	0.22	0	ERR	2	0.30
TOTALS	17		18		15		14		18		19		16	

Table 29A. Results for Sample 49, Fluorescent Yellow-orange.

OSHA COLOR SAMPLE NO. 49

COLOR NAME	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	0	0	0	0	0	0	0
RED ORANGE	0	0	0	0	0	0	0
ORANGE RED	0	0	0	0	0	0	0
PINK	0	0	0	0	0	0	0
ORANGE	19	13	17	0	19	17	20
GOLD	1	1	0	1	0	0	0
YELLOW	0	6	3	19	1	3	0
YELLOW GREEN	0	0	0	0	0	0	0
TAN	0	0	0	0	0	0	0
OLIVE	0	0	0	0	0	0	0
GREEN	0	0	0	0	0	0	0
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	0	0	0	0	0	0	0
MAGENTA	0	0	0	0	0	0	0
BROWN	0	0	0	0	0	0	0
GRAY	0	0	0	0	0	0	0
BLACK	0	0	0	0	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	9	9	11	9	11	11	12
MEDIUM	11	11	9	11	9	9	8
LOW	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	13	12	10	16	11	17	11
MEDIUM	7	8	10	3	9	3	9
LOW	0	0	0	1	0	0	0
TOTALS	20	20	20	20	20	20	20

PRIMARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	5	0.60	2	0.60	4	0.50	0	ERR	2	0.53	5	0.54	3	0.53
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
YELLOW	15	0.66	18	0.75	16	0.71	20	0.95	18	0.68	15	0.64	17	0.70
TOTALS	20		20		20		20		20		20		20	

SECONDARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	15	0.34	18	0.25	16	0.29	10	0.09	18	0.32	15	0.36	16	0.30
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	3	0.05	0	ERR	0	ERR	1	0.30
YELLOW	5	0.40	2	0.40	4	0.50	0	ERR	2	0.48	5	0.46	3	0.47
TOTALS	20		20		20		13		20		20		20	

Table 30A. Results for Sample 3, ANSI Green.

OSHA COLOR SAMPLE NO. 3

COLOR NAME	FREQUENCY						
	CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	0	0	0	0	0	0	0
RED ORANGE	0	0	0	0	0	0	0
ORANGE RED	0	0	0	0	0	0	0
PINK	0	0	0	0	0	0	0
ORANGE	0	0	0	0	0	0	0
GOLD	0	0	0	0	0	0	0
YELLOW	0	0	0	0	0	0	0
YELLOW GREEN	0	0	0	0	0	0	0
TAN	0	0	0	0	0	0	0
OLIVE	0	0	0	1	1	0	0
GREEN	11	8	10	1	17	12	13
BLUE GREEN	9	10	9	0	2	8	7
BLUE	0	2	1	0	0	0	0
PURPLE	0	0	0	0	0	0	0
MAGENTA	0	0	0	0	0	0	0
BROWN	0	0	0	2	0	0	0
GRAY	0	0	0	13	0	0	0
BLACK	0	0	0	3	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY						
	CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	0	0	0	0	0	0	0
MEDIUM	12	7	13	2	10	16	17
LOW	8	13	7	18	10	4	3
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY						
	CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	1	1	0	0	0	1	4
MEDIUM	16	13	17	3	7	15	14
LOW	3	6	3	1	13	4	2
TOTALS	20	20	20	4	20	20	20

PRIMARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	0	ERR	0	ERR	0	ERR	2	0.78	0	ERR	0	ERR	0	ERR
BLUE	1	0.75	7	0.61	4	0.55	0	ERR	1	0.50	1	0.50	2	0.55
GREEN	19	0.84	13	0.81	16	0.84	2	0.95	19	0.89	19	0.87	18	0.58
YELLOW	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
TOTALS	20		20		20		4		20		20		20	

SECONDARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
BLUE	14	0.20	8	0.26	11	0.22	0	ERR	6	0.19	13	0.17	14	0.33
GREEN	1	0.25	7	0.39	4	0.45	0	ERR	1	0.50	2	0.28	2	0.45
YELLOW	2	0.10	3	0.13	1	0.10	3	0.18	6	0.16	2	0.10	2	0.10
TOTALS	17		18		16		3		13		17		18	

Table 31A. Results for Sample 23, Retroreflective-Fluorescent Green Yellow.

OSHA COLOR SAMPLE NO. 23

COLOR NAME	FREQUENCY						
	CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	0	0	0	0	0	0	0
RED ORANGE	0	0	0	0	0	0	0
ORANGE RED	0	0	0	0	0	0	0
PINK	0	0	0	0	0	0	0
ORANGE	0	0	0	0	0	0	0
GOLD	0	0	0	0	0	0	0
YELLOW	0	0	0	0	0	0	0
YELLOW GREEN	6	3	4	0	7	7	0
TAN	0	0	0	1	0	0	0
OLIVE	0	0	0	7	0	0	0
GREEN	14	17	16	2	13	13	20
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	0	0	0	0	0	0	0
MAGENTA	0	0	0	0	0	0	0
BROWN	0	0	0	5	0	0	0
GRAY	0	0	0	5	0	0	0
BLACK	0	0	0	0	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY						
	CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	5	2	3	0	3	4	2
MEDIUM	15	15	17	11	15	16	17
LOW	0	3	0	9	2	0	1
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY						
	CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	13	9	12	0	7	14	14
MEDIUM	7	10	8	2	13	6	6
LOW	0	1	0	14	0	0	0
TOTALS	20	20	20	16	20	20	20

PRIMARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	0	ERR	0	ERR	0	ERR	6	0.80	0	ERR	0	ERR	0	ERR
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	20	0.82	20	0.91	20	0.84	6	0.86	19	0.85	20	0.78	20	0.92
YELLOW	0	ERR	0	ERR	0	ERR	1	0.60	1	0.60	0	ERR	0	ERR
TOTALS	20		20		20		13		20		20		20	

SECONDARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
BLUE	0	ERR	1	0.10	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	4	0.19	1	0.40	0	ERR	0	ERR
YELLOW	18	0.20	10	0.17	19	0.17	10	0.20	17	0.17	19	0.24	13	0.13
TOTALS	18		11		19		14		18		19		13	

Table 32A. Results for Sample 24, Fluorescent Green Yellow.

OSHA COLOR SAMPLE NO. 24

COLOR NAME	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	0	0	0	0	0	0	0
RED ORANGE	0	0	0	0	0	0	0
ORANGE RED	0	0	0	0	0	0	0
PINK	0	0	0	0	0	0	0
ORANGE	0	0	0	0	0	0	0
GOLD	0	0	0	2	0	0	0
YELLOW	0	0	0	1	0	0	0
YELLOW GREEN	12	7	9	2	10	8	7
TAN	0	0	0	5	0	0	0
OLIVE	0	0	0	7	0	0	0
GREEN	8	13	11	3	10	12	13
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	0	0	0	0	0	0	0
MAGENTA	0	0	0	0	0	0	0
BROWN	0	0	0	0	0	0	0
GRAY	0	0	0	0	0	0	0
BLACK	0	0	0	0	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	11	7	7	6	7	13	7
MEDIUM	9	12	13	11	13	7	13
LOW	0	1	0	3	0	0	0
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	16	11	14	0	8	15	10
MEDIUM	4	9	6	4	12	4	10
LOW	0	0	0	16	0	1	0
TOTALS	20	20	20	20	20	20	20

PRIMARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	18	0.77	19	0.79	20	0.78	7	0.78	14	0.77	20	0.76	20	0.84
YELLOW	2	0.53	1	0.50	0	ERR	13	0.80	6	0.66	0	ERR	0	ERR
TOTALS	20		20		20		20		20		20		20	

SECONDARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	0	ERR	0	ERR	0	ERR	4	0.23	0	ERR	0	ERR	0	ERR
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	2	0.48	1	0.50	0	ERR	9	0.18	6	0.34	20	0.24	18	0.18
YELLOW	17	0.24	16	0.24	20	0.22	7	0.22	14	0.23				
TOTALS	19		17		20		20		20		20		18	

Table 33A. Results for Sample 25, Retroreflective Green.

OSHA COLOR SAMPLE NO. 25

COLOR NAME	CW	HPS	HPSMH	LPS	MER	MH	TUN
	FREQUENCY						
RED	0	0	0	0	0	0	0
RED ORANGE	0	0	0	0	0	0	0
ORANGE RED	0	0	0	0	0	0	0
PINK	0	0	0	0	0	0	0
ORANGE	0	0	0	0	0	0	0
GOLD	0	0	0	0	0	0	0
YELLOW	0	0	0	0	0	0	0
YELLOW GREEN	0	0	0	0	1	0	0
TAN	0	0	0	0	0	0	0
OLIVE	0	0	0	0	1	0	0
GREEN	11	1	4	0	17	8	7
BLUE GREEN	8	17	15	0	1	12	13
BLUE	1	2	1	0	0	0	0
PURPLE	0	0	0	0	0	0	0
MAGENTA	0	0	0	0	0	0	0
BROWN	0	0	0	0	0	0	0
GRAY	0	0	0	6	0	0	0
BLACK	0	0	0	14	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	CW	HPS	HPSMH	LPS	MER	MH	TUN
	FREQUENCY						
HIGH	1	0	0	0	0	1	0
MEDIUM	13	5	13	0	9	15	16
LOW	6	15	7	20	11	4	4
TOTALS	20	20	20	20	20	20	20

SATURATION	CW	HPS	HPSMH	LPS	MER	MH	TUN
	FREQUENCY						
HIGH	1	4	5	0	1	3	8
MEDIUM	17	12	14	0	13	16	12
LOW	2	4	1	1	6	1	0
TOTALS	20	20	20	1	20	20	20

PRIMARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
BLUE	4	0.58	12	0.69	5	0.60	0	ERR	0	ERR	3	0.53	4	0.60
GREEN	16	0.85	8	0.77	15	0.77	0	ERR	19	0.92	17	0.79	16	0.74
YELLOW	0	ERR	0	ERR	0	ERR	0	ERR	1	0.65	0	ERR	0	ERR
TOTALS	20		20		20		0		20		20		20	

SECONDARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	0	ERR	1	0.10	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
BLUE	12	0.20	8	0.23	13	0.27	1	0.05	6	0.12	12	0.28	15	0.28
GREEN	4	0.43	11	0.33	5	0.40	0	ERR	1	0.35	3	0.47	4	0.40
YELLOW	1	0.10	0	ERR	0	ERR	0	ERR	5	0.16	3	0.10	0	ERR
TOTALS	17		20		18		1		12		18		19	

Table 34A. Results for Sample 26, Ordinary Green.

OSHA COLOR SAMPLE NO. 26

COLOR NAME	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	0	0	0	0	0	0	0
RED ORANGE	0	0	0	0	0	0	0
ORANGE RED	0	0	0	0	0	0	0
PINK	0	0	0	0	0	0	0
ORANGE	0	0	0	0	0	0	0
GOLD	0	0	0	0	0	0	0
YELLOW	0	0	0	0	0	0	0
YELLOW GREEN	0	0	0	0	1	1	0
TAN	0	0	0	0	0	0	0
OLIVE	0	0	0	2	0	0	0
GREEN	10	2	5	0	17	7	11
BLUE GREEN	10	15	14	0	2	12	9
BLUE	0	3	1	0	0	0	0
PURPLE	0	0	0	0	0	0	0
MAGENTA	0	0	0	0	0	0	0
BROWN	0	0	0	1	0	0	0
GRAY	0	0	0	17	0	0	0
BLACK	0	0	0	0	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	8	4	8	1	7	9	8
MEDIUM	12	16	12	7	13	11	12
LOW	0	0	0	12	0	0	0
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	6	4	8	0	2	6	7
MEDIUM	13	16	12	1	12	14	12
LOW	1	0	0	5	6	0	1
TOTALS	20	20	20	6	20	20	20

PRIMARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
BLUE	1	0.50	7	0.71	2	0.70	0	ERR	0	ERR	3	0.58	2	0.55
GREEN	19	0.83	13	0.79	18	0.78	4	0.95	20	0.89	17	0.78	18	0.82
YELLOW	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
TOTALS	20		20		20		4		20		20		20	

SECONDARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
BLUE	15	0.19	13	0.21	15	0.24	0	ERR	6	0.12	12	0.25	14	0.21
GREEN	1	0.50	7	0.29	2	0.30	1	0.10	0	ERR	3	0.42	2	0.45
YELLOW	3	0.10	0	ERR	2	0.20	3	0.20	13	0.11	4	0.19	1	0.30
TOTALS	19		20		19		4		19		19		17	

Table 35A. Results for Sample 39, Retroreflective Green.

OSHA COLOR SAMPLE NO. 39

COLOR NAME	CW	HPS	HPSMH	LPS	MER	MH	TUN
	FREQUENCY						
RED	0	0	0	0	0	0	0
RED ORANGE	0	0	0	0	0	0	0
ORANGE RED	0	0	0	0	0	0	0
PINK	0	0	0	0	0	0	0
ORANGE	0	0	0	0	0	0	0
GOLD	0	0	0	0	0	0	0
YELLOW	0	0	0	0	0	0	0
YELLOW GREEN	0	0	0	0	0	0	0
TAN	0	0	0	0	0	0	0
OLIVE	0	0	0	0	1	0	0
GREEN	13	1	6	0	18	8	8
BLUE GREEN	7	15	14	0	1	12	12
BLUE	0	4	0	8	0	0	0
PURPLE	0	0	0	0	0	0	0
MAGENTA	0	0	0	0	0	0	0
BROWN	0	0	0	0	0	0	0
GRAY	0	0	0	0	0	0	0
BLACK	0	0	0	12	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	CW	HPS	HPSMH	LPS	MER	MH	TUN
	FREQUENCY						
HIGH	0	0	0	0	0	0	0
MEDIUM	15	4	9	0	8	14	15
LOW	5	16	11	20	12	6	5
TOTALS	20	20	20	20	20	20	20

SATURATION	CW	HPS	HPSMH	LPS	MER	MH	TUN
	FREQUENCY						
HIGH	6	7	7	0	1	9	12
MEDIUM	14	10	12	6	17	11	8
LOW	0	3	1	11	2	0	0
TOTALS	20	20	20	17	20	20	20

PRIMARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
BLUE	2	0.70	10	0.76	4	0.63	8	1.00	0	ERR	0	ERR	2	0.55
GREEN	18	0.85	10	0.62	16	0.79	0	ERR	20	0.93	20	0.77	18	0.75
YELLOW	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
TOTALS	20		20		20		8		20		20		20	

SECONDARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	0	ERR	1	0.10	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
BLUE	14	0.19	10	0.38	15	0.22	9	0.07	6	0.13	17	0.27	17	0.26
GREEN	2	0.30	8	0.29	4	0.38	0	ERR	0	ERR	0	ERR	2	0.45
YELLOW	1	0.05	0	ERR	0	ERR	0	ERR	4	0.16	1	0.10	0	ERR
TOTALS	17		19		19		9		10		18		19	

Table 36A. Results for Sample 43, Retroreflective-Fluorescent Yellow Green.

OSHA COLOR SAMPLE NO. 43

COLOR NAME	FREQUENCY						
	CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	0	0	0	0	0	0	0
RED ORANGE	0	0	0	0	0	0	0
ORANGE RED	0	0	0	0	0	0	0
PINK	0	0	0	0	0	0	0
ORANGE	0	0	0	0	0	0	0
GOLD	0	0	0	0	0	0	0
YELLOW	4	11	8	19	3	6	9
YELLOW GREEN	15	7	12	0	13	13	9
TAN	0	0	0	0	0	0	0
OLIVE	0	0	0	1	0	0	0
GREEN	1	2	0	0	4	1	2
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	0	0	0	0	0	0	0
MAGENTA	0	0	0	0	0	0	0
BROWN	0	0	0	0	0	0	0
GRAY	0	0	0	0	0	0	0
BLACK	0	0	0	0	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY						
	CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	14	11	13	7	12	12	12
MEDIUM	6	9	7	12	8	8	8
LOW	0	0	0	1	0	0	0
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY						
	CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	12	6	7	6	11	11	4
MEDIUM	8	12	13	11	9	8	13
LOW	0	2	0	3	0	1	3
TOTALS	20	20	20	20	20	20	20

PRIMARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	2	0.65	4	0.73	3	0.63	0	ERR	6	0.67	3	0.70	4	0.69
YELLOW	18	0.80	16	0.92	17	0.85	20	0.97	14	0.74	17	0.79	16	0.87
TOTALS	20		20		20		20		20		20		20	

SECONDARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	0	ERR	0	ERR	0	ERR	3	0.07	0	ERR	0	ERR	0	ERR
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	18	0.20	13	0.10	16	0.16	3	0.12	14	0.26	16	0.22	13	0.16
YELLOW	2	0.35	4	0.28	3	0.37	0	ERR	6	0.33	3	0.30	4	0.31
TOTALS	20		17		19		6		20		19		17	

Table 37A. Results for Sample 50, Fluorescent Green Yellow.

OSHA COLOR SAMPLE NO. 50

COLOR NAME	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	0	0	0	0	0	0	0
RED ORANGE	0	0	0	0	0	0	0
ORANGE RED	0	0	0	0	0	0	0
PINK	0	0	0	0	0	0	0
ORANGE	0	0	0	0	0	0	0
GOLD	0	0	0	0	0	0	0
YELLOW	6	13	6	20	5	5	10
YELLOW GREEN	14	7	13	0	14	14	9
TAN	0	0	0	0	0	0	0
OLIVE	0	0	0	0	0	0	0
GREEN	0	0	1	0	1	1	1
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	0	0	0	0	0	0	0
MAGENTA	0	0	0	0	0	0	0
BROWN	0	0	0	0	0	0	0
GRAY	0	0	0	0	0	0	0
BLACK	0	0	0	0	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	18	15	19	14	15	16	16
MEDIUM	2	5	1	6	5	4	4
LOW	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	13	11	10	18	12	14	9
MEDIUM	6	8	9	2	8	4	10
LOW	1	1	1	0	0	2	1
TOTALS	20	20	20	20	20	20	20

PRIMARY HUES	CW FREQ	CW AVG%	HPS FREQ	HPS AVG%	HPSMH FREQ	HPSMH AVG%	LPS FREQ	LPS AVG%	MER FREQ	MER AVG%	MH FREQ	MH AVG%	TUN FREQ	TUN AVG%
RED	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	2	0.65	1	0.70	7	0.62	0	ERR	8	0.69	2	0.88	3	0.60
YELLOW	18	0.78	19	0.90	13	0.82	20	0.98	12	0.74	18	0.79	17	0.86
TOTALS	20		20		20		20		20		20		20	

SECONDARY HUES	CW FREQ	CW AVG%	HPS FREQ	HPS AVG%	HPSMH FREQ	HPSMH AVG%	LPS FREQ	LPS AVG%	MER FREQ	MER AVG%	MH FREQ	MH AVG%	TUN FREQ	TUN AVG%
RED	0	ERR	0	ERR	0	ERR	3	0.08	0	ERR	0	ERR	0	ERR
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	18	0.22	12	0.16	12	0.20	2	0.05	12	0.26	16	0.24	14	0.17
YELLOW	2	0.35	1	0.30	7	0.38	0	ERR	8	0.31	2	0.13	3	0.40
TOTALS	20		13		19		5		20		18		17	

Table 38A. Results for Sample 51, Fluorescent Green.

OSHA COLOR SAMPLE NO. 51

COLOR NAME	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	0	0	0	0	0	0	0
RED ORANGE	0	0	0	0	0	0	0
ORANGE RED	0	0	0	0	0	0	0
PINK	0	0	0	0	0	0	0
ORANGE	0	0	0	0	0	0	0
GOLD	0	0	0	1	0	0	0
YELLOW	0	0	0	2	0	0	0
YELLOW GREEN	6	4	5	1	10	8	5
TAN	0	0	0	3	0	0	0
OLIVE	0	0	0	7	0	0	0
GREEN	13	16	15	3	10	12	15
BLUE GREEN	1	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	0	0	0	0	0	0	0
MAGENTA	0	0	0	0	0	0	0
BROWN	0	0	0	1	0	0	0
GRAY	0	0	0	2	0	0	0
BLACK	0	0	0	0	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	8	7	6	2	3	8	5
MEDIUM	12	12	14	10	17	12	15
LOW	0	1	0	8	0	0	0
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	12	6	8	0	7	12	12
MEDIUM	8	11	10	4	11	7	7
LOW	0	3	2	14	2	1	1
TOTALS	20	20	20	18	20	20	20

PRIMARY HUES	CW FREQ	CW AVG%	HPS FREQ	HPS AVG%	HPSMH FREQ	HPSMH AVG%	LPS FREQ	LPS AVG%	MER FREQ	MER AVG%	MH FREQ	MH AVG%	TUN FREQ	TUN AVG%
RED	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	20	0.82	20	0.82	20	0.86	7	0.82	18	0.78	18	0.79	20	0.84
YELLOW	0	ERR	0	ERR	0	ERR	11	0.86	2	0.58	2	0.50	0	ERR
TOTALS	20		20		20		18		20		20		20	

SECONDARY HUES	CW FREQ	CW AVG%	HPS FREQ	HPS AVG%	HPSMH FREQ	HPSMH AVG%	LPS FREQ	LPS AVG%	MER FREQ	MER AVG%	MH FREQ	MH AVG%	TUN FREQ	TUN AVG%
RED	0	ERR	0	ERR	0	ERR	4	0.10	0	ERR	0	ERR	0	ERR
BLUE	1	0.10	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	6	0.19	2	0.43	2	0.50	0	ERR
YELLOW	15	0.23	15	0.25	17	0.16	6	0.21	17	0.24	16	0.24	16	0.20
TOTALS	16		15		17		16		19		18		16	

Table 39A. Results for Sample 55, Retroreflective Green.

OSHA COLOR SAMPLE NO. 55

COLOR NAME	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	0	0	0	0	0	0	0
RED ORANGE	0	0	0	0	0	0	0
ORANGE RED	0	0	0	0	0	0	0
PINK	0	0	0	0	0	0	0
ORANGE	0	0	0	0	0	0	0
GOLD	0	0	0	0	0	0	0
YELLOW	0	0	0	0	0	0	0
YELLOW GREEN	0	0	0	0	1	0	0
TAN	0	0	0	0	0	0	0
OLIVE	0	0	0	0	0	0	0
GREEN	14	4	7	0	18	10	8
BLUE GREEN	5	12	13	0	1	10	11
BLUE	1	4	0	1	0	0	1
PURPLE	0	0	0	0	0	0	0
MAGENTA	0	0	0	0	0	0	0
BROWN	0	0	0	0	0	0	0
GRAY	0	0	0	3	0	0	0
BLACK	0	0	0	16	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	1	0	0	0	0	0	1
MEDIUM	11	2	11	0	10	15	11
LOW	8	18	9	20	10	5	8
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	1	3	4	0	1	3	7
MEDIUM	17	14	15	0	14	14	11
LOW	2	3	1	4	5	3	2
TOTALS	20	20	20	4	20	20	20

PRIMARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
BLUE	2	0.55	9	0.73	2	0.55	1	1.00	0	ERR	0	ERR	5	0.60
GREEN	18	0.87	11	0.78	18	0.79	0	ERR	20	0.89	20	0.84	15	0.82
YELLOW	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
TOTALS	20		20		20		1		20		20		20	

SECONDARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
BLUE	12	0.18	11	0.22	17	0.22	3	0.04	8	0.14	16	0.20	13	0.20
GREEN	2	0.45	8	0.30	2	0.45	0	ERR	0	ERR	0	ERR	5	0.40
YELLOW	2	0.08	0	ERR	0	ERR	0	ERR	7	0.17	1	0.05	1	0.10
TOTALS	16		19		19		3		15		17		19	

Table 40A. Results for Sample 2, ANSI Blue.

OSHA COLOR SAMPLE NO. 2

COLOR NAME	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	0	0	0	0	0	0	0
RED ORANGE	0	0	0	0	0	0	0
ORANGE RED	0	0	0	0	0	0	0
PINK	0	0	0	0	0	0	0
ORANGE	0	0	0	0	0	0	0
GOLD	0	0	0	0	0	0	0
YELLOW	0	0	0	0	0	0	0
YELLOW GREEN	0	0	0	0	0	0	0
TAN	0	0	0	0	0	0	0
OLIVE	0	0	0	0	0	0	0
GREEN	0	0	0	0	0	0	0
BLUE GREEN	0	0	0	0	0	0	0
BLUE	20	20	20	0	12	20	20
PURPLE	0	0	0	0	8	0	0
MAGENTA	0	0	0	0	0	0	0
BROWN	0	0	0	3	0	0	0
GRAY	0	0	0	12	0	0	0
BLACK	0	0	0	5	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	0	0	0	0	0	0	0
MEDIUM	14	7	13	0	10	17	15
LOW	6	13	7	20	10	3	5
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	6	4	5	0	3	4	5
MEDIUM	12	12	13	0	12	12	13
LOW	2	4	2	5	5	4	2
TOTALS	20	20	20	5	20	20	20

PRIMARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	0	ERR	0	ERR	0	ERR	3	0.80	0	ERR	0	ERR	0	ERR
BLUE	20	0.99	20	0.98	20	0.99	0	ERR	20	0.83	20	0.98	20	0.97
GREEN	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
YELLOW	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
TOTALS	20		20		20		3		20		20		20	

SECONDARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	3	0.07	2	0.10	2	0.08	0	ERR	16	0.19	4	0.08	2	0.05
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	2	0.10	0	ERR	0	ERR	0	ERR	1	0.05	4	0.13
YELLOW	0	ERR	0	ERR	0	ERR	4	0.16	0	ERR	1	0.05	0	ERR
TOTALS	3		4		2		4		16		6		6	

Table 41A. Results for Sample 27, Retroreflective Blue.

OSHA COLOR SAMPLE NO. 27

COLOR NAME	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	0	0	0	0	0	0	0
RED ORANGE	0	0	0	0	0	0	0
ORANGE RED	0	0	0	0	0	0	0
PINK	0	0	0	0	0	0	0
ORANGE	0	0	0	0	0	0	0
GOLD	0	0	0	0	0	0	0
YELLOW	0	0	0	0	0	0	0
YELLOW GREEN	0	0	0	0	0	0	0
TAN	0	0	0	0	0	0	0
OLIVE	0	0	0	0	0	0	0
GREEN	0	0	0	0	0	0	0
BLUE GREEN	0	0	0	0	0	0	0
BLUE	20	20	20	5	19	20	20
PURPLE	0	0	0	0	1	0	0
MAGENTA	0	0	0	0	0	0	0
BROWN	0	0	0	0	0	0	0
GRAY	0	0	0	0	0	0	0
BLACK	0	0	0	15	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	0	0	0	0	0	0	1
MEDIUM	11	3	13	0	1	15	13
LOW	9	17	7	20	19	5	6
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	12	12	12	1	8	11	12
MEDIUM	8	8	7	2	12	9	8
LOW	0	0	1	8	0	0	0
TOTALS	20	20	20	11	20	20	20

PRIMARY HUES	CW FREQ	CW AVG%	HPS FREQ	HPS AVG%	HPSMH FREQ	HPSMH AVG%	LPS FREQ	LPS AVG%	MER FREQ	MER AVG%	MH FREQ	MH AVG%	TUN FREQ	TUN AVG%
RED	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
BLUE	20	0.99	20	0.98	20	0.99	5	1.00	20	0.96	20	0.98	20	0.98
GREEN	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
YELLOW	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
TOTALS	20		20		20		5		20		20		20	

SECONDARY HUES	CW FREQ	CW AVG%	HPS FREQ	HPS AVG%	HPSMH FREQ	HPSMH AVG%	LPS FREQ	LPS AVG%	MER FREQ	MER AVG%	MH FREQ	MH AVG%	TUN FREQ	TUN AVG%
RED	3	0.05	2	0.10	2	0.08	0	ERR	6	0.13	2	0.05	2	0.05
BLUE	0	ERR	0	ERR	0	ERR	6	0.05	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	2	0.08	2	0.08	0	ERR	0	ERR	2	0.10	3	0.12
YELLOW	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	1	0.10	0	ERR
TOTALS	3		4		4		6		6		5		5	

Table 42A. Results for Sample 28, Ordinary Blue.

OSHA COLOR SAMPLE NO. 28

COLOR NAME	CW	HPS	HPSMH	LPS	MER	MH	TUN
	FREQUENCY						
RED	0	0	0	0	0	0	0
RED ORANGE	0	0	0	0	0	0	0
ORANGE RED	0	0	0	0	0	0	0
PINK	0	0	0	0	0	0	0
ORANGE	0	0	0	0	0	0	0
GOLD	0	0	0	0	0	0	0
YELLOW	0	0	0	0	0	0	0
YELLOW GREEN	0	0	0	0	0	0	0
TAN	0	0	0	0	0	0	0
OLIVE	0	0	0	0	0	0	0
GREEN	0	0	0	0	0	0	0
BLUE GREEN	0	0	0	0	0	0	0
BLUE	20	20	20	14	19	20	20
PURPLE	0	0	0	0	1	0	0
MAGENTA	0	0	0	0	0	0	0
BROWN	0	0	0	0	0	0	0
GRAY	0	0	0	0	0	0	0
BLACK	0	0	0	6	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	CW	HPS	HPSMH	LPS	MER	MH	TUN
	FREQUENCY						
HIGH	7	0	6	0	3	7	8
MEDIUM	13	17	13	0	16	13	12
LOW	0	3	1	20	1	0	0
TOTALS	20	20	20	20	20	20	20

SATURATION	CW	HPS	HPSMH	LPS	MER	MH	TUN
	FREQUENCY						
HIGH	12	13	11	0	8	15	12
MEDIUM	7	7	9	5	12	5	8
LOW	1	0	0	14	0	0	0
TOTALS	20	20	20	19	20	20	20

PRIMARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
BLUE	20	0.98	20	0.98	20	0.97	14	0.99	20	0.97	20	0.96	20	0.95
GREEN	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
YELLOW	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
TOTALS	20		20		20		14		20		20		20	

SECONDARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	1	0.05	1	0.10	2	0.05	1	0.10	7	0.10	1	0.05	1	0.05
BLUE	0	ERR	0	ERR	0	ERR	5	0.05	0	ERR	0	ERR	0	ERR
GREEN	4	0.09	3	0.08	5	0.09	0	ERR	0	ERR	5	0.13	7	0.13
YELLOW	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	1	0.05	0	ERR
TOTALS	5		4		7		6		7		7		8	

Table 43A. Results for Sample 40, Retroreflective Blue.

OSHA COLOR SAMPLE NO. 40

COLOR NAME	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	0	0	0	0	0	0	0
RED ORANGE	0	0	0	0	0	0	0
ORANGE RED	0	0	0	0	0	0	0
PINK	0	0	0	0	0	0	0
ORANGE	0	0	0	0	0	0	0
GOLD	0	0	0	0	0	0	0
YELLOW	0	0	0	0	0	0	0
YELLOW GREEN	0	0	0	0	0	0	0
TAN	0	0	0	0	0	0	0
OLIVE	0	0	0	0	0	0	0
GREEN	0	0	0	0	0	0	0
BLUE GREEN	0	0	0	0	0	0	0
BLUE	20	20	20	5	18	20	20
PURPLE	0	0	0	0	2	0	0
MAGENTA	0	0	0	0	0	0	0
BROWN	0	0	0	0	0	0	0
GRAY	0	0	0	0	0	0	0
BLACK	0	0	0	15	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	0	0	0	0	0	0	0
MEDIUM	2	1	2	0	0	2	3
LOW	18	19	18	20	20	18	17
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	12	10	12	0	9	10	12
MEDIUM	7	7	6	4	10	10	6
LOW	1	3	2	8	1	0	2
TOTALS	20	20	20	12	20	20	20

PRIMARY HUES	CW FREQ	CW AVG%	HPS FREQ	HPS AVG%	HPSMH FREQ	HPSMH AVG%	LPS FREQ	LPS AVG%	MER FREQ	MER AVG%	MH FREQ	MH AVG%	TUN FREQ	TUN AVG%
RED	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
BLUE	20	0.99	20	0.99	20	0.99	5	1.00	20	0.96	20	0.98	20	1.00
GREEN	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
YELLOW	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
TOTALS	20		20		20		5		20		20		20	

SECONDARY HUES	CW FREQ	CW AVG%	HPS FREQ	HPS AVG%	HPSMH FREQ	HPSMH AVG%	LPS FREQ	LPS AVG%	MER FREQ	MER AVG%	MH FREQ	MH AVG%	TUN FREQ	TUN AVG%
RED	4	0.06	2	0.08	2	0.08	0	ERR	6	0.15	4	0.09	1	0.10
BLUE	0	ERR	0	ERR	0	ERR	7	0.05	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	1	0.05	2	0.08	0	ERR	0	ERR	1	0.10	0	ERR
YELLOW	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
TOTALS	4		3		4		7		6		5		1	

Table 44A. Results for Sample 52, Fluorescent Blue.

OSHA COLOR SAMPLE NO. 52

COLOR NAME	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	0	0	0	0	0	0	0
RED ORANGE	0	0	0	0	0	0	0
ORANGE RED	0	0	0	0	0	0	0
PINK	0	0	0	0	0	0	0
ORANGE	0	0	0	0	0	0	0
GOLD	0	0	0	0	0	0	0
YELLOW	0	0	0	0	0	0	0
YELLOW GREEN	0	0	0	0	0	0	0
TAN	0	0	0	0	0	0	0
OLIVE	0	0	0	0	0	0	0
GREEN	0	0	0	0	0	0	0
BLUE GREEN	0	0	0	0	0	0	0
BLUE	20	20	20	0	20	20	20
PURPLE	0	0	0	1	0	0	0
MAGENTA	0	0	0	0	0	0	0
BROWN	0	0	0	4	0	0	0
GRAY	0	0	0	13	0	0	0
BLACK	0	0	0	2	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	4	2	3	0	2	6	6
MEDIUM	15	14	14	4	17	14	13
LOW	1	4	3	16	1	0	1
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	7	5	8	0	3	7	7
MEDIUM	12	13	12	2	15	13	12
LOW	1	2	0	5	2	0	1
TOTALS	20	20	20	7	20	20	20

PRIMARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	0	ERR	0	ERR	0	ERR	4	0.66	0	ERR	0	ERR	0	ERR
BLUE	20	0.99	20	0.99	20	0.99	0	ERR	20	0.99	20	0.99	20	0.96
GREEN	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
YELLOW	0	ERR	0	ERR	0	ERR	1	0.50	0	ERR	0	ERR	0	ERR
TOTALS	20		20		20		5		20		20		20	

SECONDARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	0	ERR	1	0.10	2	0.08	1	0.50	2	0.08	0	ERR	1	0.05
BLUE	0	ERR	0	ERR	0	ERR	1	0.50	0	ERR	0	ERR	0	ERR
GREEN	2	0.10	1	0.05	0	ERR	0	ERR	0	ERR	4	0.05	7	0.11
YELLOW	0	ERR	0	ERR	0	ERR	3	0.28	0	ERR	0	ERR	0	ERR
TOTALS	2		2		2		5		2		4		8	

Table 45A. Results for Sample 54, Retroreflective Blue.

OSHA COLOR SAMPLE NO. 54

COLOR NAME	CW	HPS	HPSMH	LPS	MER	MH	TUN
	FREQUENCY						
RED	0	0	0	0	0	0	0
RED ORANGE	0	0	0	0	0	0	0
ORANGE RED	0	0	0	0	0	0	0
PINK	0	0	0	0	0	0	0
ORANGE	0	0	0	0	0	1	0
GOLD	0	0	0	0	0	0	0
YELLOW	0	0	0	0	0	0	0
YELLOW GREEN	0	0	0	0	0	0	0
TAN	0	0	0	0	0	0	0
OLIVE	0	0	0	0	0	0	0
GREEN	0	0	0	0	0	0	0
BLUE GREEN	0	0	0	0	0	0	2
BLUE	20	20	20	4	18	19	18
PURPLE	0	0	0	0	2	0	0
MAGENTA	0	0	0	0	0	0	0
BROWN	0	0	0	0	0	0	0
GRAY	0	0	0	0	0	0	0
BLACK	0	0	0	16	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	CW	HPS	HPSMH	LPS	MER	MH	TUN
	FREQUENCY						
HIGH	2	0	1	0	0	1	0
MEDIUM	8	4	5	0	0	7	8
LOW	10	16	14	20	20	12	12
TOTALS	20	20	20	20	20	20	20

SATURATION	CW	HPS	HPSMH	LPS	MER	MH	TUN
	FREQUENCY						
HIGH	9	13	11	0	6	11	10
MEDIUM	9	5	9	1	11	9	9
LOW	2	2	0	7	3	0	1
TOTALS	20	20	20	8	20	20	20

PRIMARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	1	0.50	0	ERR
BLUE	20	0.99	19	0.99	20	0.97	4	1.00	20	0.94	19	0.98	20	0.96
GREEN	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
YELLOW	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
TOTALS	20		19		20		4		20		20		20	

SECONDARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	2	0.08	1	0.10	2	0.10	0	ERR	9	0.13	3	0.07	2	0.10
BLUE	0	ERR	0	ERR	0	ERR	5	0.05	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	2	0.05	5	0.08	0	ERR	0	ERR	2	0.05	3	0.18
YELLOW	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	1	0.50	0	ERR
TOTALS	2		3		7		5		9		6		5	

Table 46A. Results for Sample 1, ANSI Purple.

OSHA COLOR SAMPLE NO. 1

COLOR NAME	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	0	0	0	0	0	0	0
RED ORANGE	0	0	0	0	0	0	0
ORANGE RED	0	0	0	0	0	0	0
PINK	0	0	0	0	0	0	1
ORANGE	0	0	0	0	0	0	0
GOLD	0	0	0	0	0	0	0
YELLOW	0	0	0	0	0	0	0
YELLOW GREEN	0	0	0	0	0	0	0
TAN	0	0	0	2	0	0	0
OLIVE	0	0	0	5	0	0	0
GREEN	0	0	0	1	0	0	0
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	20	19	20	0	20	20	15
MAGENTA	0	1	0	0	0	0	4
BROWN	0	0	0	5	0	0	0
GRAY	0	0	0	7	0	0	0
BLACK	0	0	0	0	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	8	9	5	2	4	7	3
MEDIUM	11	11	14	13	13	12	16
LOW	1	0	1	5	3	1	1
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	2	2	1	0	0	2	1
MEDIUM	15	12	15	4	15	15	13
LOW	3	6	4	10	5	3	6
TOTALS	20	20	20	14	20	20	20

PRIMARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	10	0.55	11	0.61	7	0.67	4	0.76	4	0.50	8	0.54	16	0.75
BLUE	10	0.66	9	0.59	13	0.59	0	ERR	16	0.65	12	0.60	4	0.60
GREEN	0	ERR	0	ERR	0	ERR	6	0.85	0	ERR	0	ERR	0	ERR
YELLOW	0	ERR	0	ERR	0	ERR	3	0.67	0	ERR	0	ERR	0	ERR
TOTALS	20		20		20		13		20		20		20	

SECONDARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	10	0.34	9	0.41	13	0.41	1	0.40	16	0.35	12	0.40	4	0.40
BLUE	10	0.45	11	0.39	7	0.33	0	ERR	4	0.50	8	0.46	16	0.25
GREEN	0	ERR	0	ERR	0	ERR	3	0.22	0	ERR	0	ERR	0	ERR
YELLOW	0	ERR	0	ERR	0	ERR	10	0.19	0	ERR	0	ERR	0	ERR
TOTALS	20		20		20		14		20		20		20	

Table 47A. Results for Sample 29, Retroreflective-Fluorescent Magenta.

OSHA COLOR SAMPLE NO. 29

COLOR NAME	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	1	0	0	0	2	0	1
RED ORANGE	0	2	4	0	0	2	4
ORANGE RED	0	4	3	0	0	4	0
PINK	15	9	13	0	17	13	12
ORANGE	0	5	0	20	0	0	3
GOLD	0	0	0	0	0	0	0
YELLOW	0	0	0	0	0	0	0
YELLOW GREEN	0	0	0	0	0	0	0
TAN	0	0	0	0	0	0	0
OLIVE	0	0	0	0	0	0	0
GREEN	0	0	0	0	0	0	0
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	0	0	0	0	0	0	0
MAGENTA	4	0	0	0	1	1	0
BROWN	0	0	0	0	0	0	0
GRAY	0	0	0	0	0	0	0
BLACK	0	0	0	0	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	11	11	12	9	7	10	9
MEDIUM	9	8	7	11	13	10	11
LOW	0	1	1	0	0	0	0
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	12	9	7	5	13	14	6
MEDIUM	8	7	11	14	7	6	12
LOW	0	4	2	1	0	0	2
TOTALS	20	20	20	20	20	20	20

PRIMARY HUES	CW FREQ	CW AVG%	HPS FREQ	HPS AVG%	HPSMH FREQ	HPSMH AVG%	LPS FREQ	LPS AVG%	MER FREQ	MER AVG%	MH FREQ	MH AVG%	TUN FREQ	TUN AVG%
RED	19	0.91	19	0.79	20	0.89	6	0.58	20	0.91	20	0.86	20	0.83
BLUE	1	0.70	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
YELLOW	0	ERR	1	0.70	0	ERR	14	0.67	0	ERR	0	ERR	0	ERR
TOTALS	20		20		20		20		20		20		20	

SECONDARY HUES	CW FREQ	CW AVG%	HPS FREQ	HPS AVG%	HPSMH FREQ	HPSMH AVG%	LPS FREQ	LPS AVG%	MER FREQ	MER AVG%	MH FREQ	MH AVG%	TUN FREQ	TUN AVG%
RED	1	0.30	1	0.30	0	ERR	14	0.33	0	ERR	0	ERR	0	ERR
BLUE	11	0.13	1	0.20	6	0.11	0	ERR	12	0.11	7	0.09	4	0.14
GREEN	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
YELLOW	2	0.18	15	0.24	11	0.15	6	0.42	4	0.10	12	0.18	15	0.19
TOTALS	14		17		17		20		16		19		19	

Table 48A. Results for Sample 30, Fluorescent Magenta.

OSHA COLOR SAMPLE NO. 30

COLOR NAME	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	0	0	0	0	0	0	0
RED ORANGE	0	0	0	0	0	0	0
ORANGE RED	0	0	0	0	0	0	1
PINK	13	19	17	0	12	16	18
ORANGE	0	0	0	3	0	0	0
GOLD	0	0	0	0	0	0	0
YELLOW	0	0	0	17	0	0	0
YELLOW GREEN	0	0	0	0	0	0	0
TAN	0	0	0	0	0	0	0
OLIVE	0	0	0	0	0	0	0
GREEN	0	0	0	0	0	0	0
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	3	1	1	0	4	0	0
MAGENTA	4	0	2	0	4	4	1
BROWN	0	0	0	0	0	0	0
GRAY	0	0	0	0	0	0	0
BLACK	0	0	0	0	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	13	18	18	11	11	16	14
MEDIUM	7	2	2	9	9	4	6
LOW	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	12	7	9	11	12	15	9
MEDIUM	8	10	10	8	8	2	9
LOW	0	3	1	1	0	3	2
TOTALS	20	20	20	20	20	20	20

PRIMARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	19	0.86	19	0.94	20	0.92	0	ERR	20	0.87	20	0.88	20	0.92
BLUE	1	0.80	1	0.90	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
YELLOW	0	ERR	0	ERR	0	ERR	20	0.91	0	ERR	0	ERR	0	ERR
TOTALS	20		20		20		20		20		20		20	

SECONDARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	1	0.20	1	0.10	0	ERR	12	0.13	0	ERR	0	ERR	0	ERR
BLUE	14	0.19	6	0.09	13	0.12	0	ERR	18	0.15	13	0.17	9	0.14
GREEN	0	ERR	0	ERR	0	ERR	3	0.08	0	ERR	0	ERR	0	ERR
YELLOW	0	ERR	5	0.12	1	0.10	0	ERR	0	ERR	2	0.10	3	0.15
TOTALS	15		12		14		15		18		15		12	

Table 49A. Results for Sample 44, Fluorescent Magenta.

OSHA COLOR SAMPLE NO. 44

COLOR NAME	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	1	1	1	1	0	3	3
RED ORANGE	0	1	0	2	0	0	3
ORANGE RED	0	3	0	2	0	0	0
PINK	15	14	13	0	11	9	10
ORANGE	0	0	0	15	0	0	1
GOLD	0	0	0	0	0	0	0
YELLOW	0	0	0	0	0	0	0
YELLOW GREEN	0	0	0	0	0	0	0
TAN	0	0	0	0	0	0	0
OLIVE	0	0	0	0	0	0	0
GREEN	0	0	0	0	0	1	0
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	0	0	0	0	2	1	0
MAGENTA	4	1	6	0	7	6	3
BROWN	0	0	0	0	0	0	0
GRAY	0	0	0	0	0	0	0
BLACK	0	0	0	0	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	10	5	8	3	6	8	7
MEDIUM	10	15	12	17	14	12	13
LOW	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	16	9	14	4	16	17	15
MEDIUM	3	9	6	16	4	3	5
LOW	1	2	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

PRIMARY HUES	CW FREQ	CW AVG%	HPS FREQ	HPS AVG%	HPSMH FREQ	HPSMH AVG%	LPS FREQ	LPS AVG%	MER FREQ	MER AVG%	MH FREQ	MH AVG%	TUN FREQ	TUN AVG%
RED	19	0.89	20	0.87	20	0.89	17	0.69	20	0.89	19	0.87	20	0.85
BLUE	1	0.90	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	1	0.70	0	ERR
YELLOW	0	ERR	0	ERR	0	ERR	3	0.60	0	ERR	0	ERR	0	ERR
TOTALS	20		20		20		20		20		20		20	

SECONDARY HUES	CW FREQ	CW AVG%	HPS FREQ	HPS AVG%	HPSMH FREQ	HPSMH AVG%	LPS FREQ	LPS AVG%	MER FREQ	MER AVG%	MH FREQ	MH AVG%	TUN FREQ	TUN AVG%
RED	1	0.10	0	ERR	0	ERR	3	0.40	0	ERR	0	ERR	0	ERR
BLUE	14	0.15	7	0.10	16	0.14	0	ERR	16	0.14	14	0.17	9	0.18
GREEN	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
YELLOW	0	ERR	8	0.24	0	ERR	17	0.31	0	ERR	5	0.08	9	0.16
TOTALS	15		15		16		20		16		19		18	

Table 50A. Results for Sample 53, Fluorescent Magenta.

OSHA COLOR SAMPLE NO. 53

COLOR NAME	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	0	1	0	8	0	0	3
RED ORANGE	0	1	0	2	0	0	1
ORANGE RED	0	0	0	1	0	0	0
PINK	8	12	9	0	7	11	8
ORANGE	0	0	0	8	0	0	0
GOLD	0	0	0	0	0	0	0
YELLOW	0	0	0	0	0	0	0
YELLOW GREEN	0	0	0	0	0	0	0
TAN	0	0	0	0	0	0	0
OLIVE	0	0	0	0	0	0	0
GREEN	0	0	0	0	0	0	0
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	3	2	4	0	5	3	2
MAGENTA	9	4	7	1	8	6	6
BROWN	0	0	0	0	0	0	0
GRAY	0	0	0	0	0	0	0
BLACK	0	0	0	0	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	9	5	7	0	3	4	5
MEDIUM	11	15	13	15	17	16	15
LOW	0	0	0	5	0	0	0
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	15	10	13	4	16	15	12
MEDIUM	5	7	7	10	4	5	8
LOW	0	3	0	6	0	0	0
TOTALS	20	20	20	20	20	20	20

PRIMARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	20	0.83	20	0.85	20	0.81	20	0.79	18	0.79	20	0.81	20	0.88
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	2	0.75	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
YELLOW	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
TOTALS	20		20		20		20		20		20		20	

SECONDARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	0	ERR	0	ERR	0	ERR	0	ERR	2	0.25	0	ERR	0	ERR
BLUE	19	0.18	15	0.20	17	0.23	1	0.10	18	0.21	19	0.20	16	0.15
GREEN	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
YELLOW	0	ERR	1	0.05	0	ERR	18	0.23	0	ERR	0	ERR	1	0.05
TOTALS	19		16		17		19		20		19		17	

Table 51A. Results for Sample 7, ANSI Brown.

OSHA COLOR SAMPLE NO. 7

COLOR NAME	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	0	0	0	0	0	0	1
RED ORANGE	0	0	0	0	0	0	0
ORANGE RED	0	0	0	0	0	0	0
PINK	0	0	0	0	0	0	0
ORANGE	0	1	0	0	0	0	0
GOLD	0	0	0	0	0	0	0
YELLOW	0	0	0	2	0	0	0
YELLOW GREEN	0	0	0	0	0	0	0
TAN	0	1	3	6	1	2	0
OLIVE	0	7	2	6	7	0	0
GREEN	0	0	0	2	1	0	0
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	0	0	0	0	0	0	0
MAGENTA	0	0	0	0	0	0	0
BROWN	20	11	15	2	11	18	19
GRAY	0	0	0	2	0	0	0
BLACK	0	0	0	0	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	0	0	0	3	0	0	0
MEDIUM	3	7	5	11	7	4	3
LOW	17	13	15	6	13	16	17
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	0	0	1	0	0	1	0
MEDIUM	13	10	10	5	6	9	9
LOW	7	10	9	13	14	10	11
TOTALS	20	20	20	18	20	20	20

PRIMARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	12	0.75	8	0.79	11	0.79	4	0.84	6	0.93	14	0.76	15	0.79
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	2	0.65	7	0.70	3	0.73	7	0.87	8	0.86	2	0.60	0	ERR
YELLOW	6	0.71	5	0.74	6	0.73	7	0.82	6	0.80	4	0.69	5	0.68
TOTALS	20		20		20		18		20		20		20	

SECONDARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	4	0.24	3	0.33	6	0.27	2	0.30	4	0.20	4	0.31	5	0.32
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	4	0.45	3	0.20	4	0.33	6	0.12	4	0.25	4	0.26	1	0.50
YELLOW	11	0.24	14	0.25	9	0.21	11	0.14	10	0.10	12	0.26	13	0.20
TOTALS	19		20		19		19		18		20		19	

Table 52A. Results for Sample 38, Retroreflective Brown.

OSHA COLOR SAMPLE NO. 38

COLOR NAME	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	0	0	0	0	0	1	0
RED ORANGE	0	0	0	0	0	0	0
ORANGE RED	0	0	0	0	0	0	0
PINK	0	0	0	0	0	0	0
ORANGE	0	0	0	0	0	1	0
GOLD	0	0	0	0	0	0	0
YELLOW	0	0	0	0	0	0	0
YELLOW GREEN	0	0	0	0	0	0	0
TAN	0	1	0	4	0	1	0
OLIVE	0	6	2	8	5	1	0
GREEN	0	0	0	2	1	0	0
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	0	0	0	0	0	0	0
MAGENTA	0	0	0	0	0	0	0
BROWN	20	13	18	2	14	16	20
GRAY	0	0	0	4	0	0	0
BLACK	0	0	0	0	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	0	1	1	1	0	0	0
MEDIUM	4	7	5	12	3	4	6
LOW	16	12	14	7	17	16	14
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	1	0	0	0	1	1	1
MEDIUM	11	10	10	3	8	12	9
LOW	8	10	10	14	11	7	10
TOTALS	20	20	20	17	20	20	20

PRIMARY HUES	CW FREQ	CW AVG%	HPS FREQ	HPS AVG%	HPSMH FREQ	HPSMH AVG%	LPS FREQ	LPS AVG%	MER FREQ	MER AVG%	MH FREQ	MH AVG%	TUN FREQ	TUN AVG%
RED	10	0.79	10	0.80	9	0.79	3	0.77	5	0.95	12	0.78	16	0.78
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	2	0.75	6	0.71	2	0.80	7	0.88	8	0.84	2	0.73	0	ERR
YELLOW	8	0.60	4	0.78	9	0.68	6	0.79	7	0.74	6	0.63	4	0.80
TOTALS	20		20		20		16		20		20		20	

SECONDARY HUES	CW FREQ	CW AVG%	HPS FREQ	HPS AVG%	HPSMH FREQ	HPSMH AVG%	LPS FREQ	LPS AVG%	MER FREQ	MER AVG%	MH FREQ	MH AVG%	TUN FREQ	TUN AVG%
RED	8	0.36	2	0.30	9	0.34	2	0.35	7	0.21	5	0.34	3	0.27
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	3	0.50	2	0.45	2	0.35	4	0.16	3	0.37	3	0.43	2	0.25
YELLOW	8	0.16	14	0.23	7	0.12	9	0.17	9	0.09	12	0.20	14	0.21
TOTALS	19		18		18		15		19		20		19	

Table 53A. Results for Sample 10, ANSI White.

OSHA COLOR SAMPLE NO. 10

COLOR NAME	FREQUENCY						
	CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	0	0	0	0	0	0	0
RED ORANGE	0	0	0	0	0	0	0
ORANGE RED	0	0	0	0	0	0	0
PINK	0	0	0	0	0	0	0
ORANGE	0	0	0	0	0	0	0
GOLD	0	0	0	0	0	0	0
YELLOW	0	0	0	20	0	0	0
YELLOW GREEN	0	0	0	0	0	0	0
TAN	0	0	0	0	0	0	0
OLIVE	0	0	0	0	0	0	0
GREEN	0	0	0	0	0	0	0
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	0	0	0	0	0	0	0
MAGENTA	0	0	0	0	0	0	0
BROWN	0	0	0	0	0	0	0
GRAY	0	0	0	0	1	1	0
BLACK	0	0	0	0	0	0	0
WHITE	20	20	20	0	19	19	20
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY						
	CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	20	20	20	15	20	20	20
MEDIUM	0	0	0	5	0	0	0
LOW	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY						
	CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	0	0	0	20	0	0	0
MEDIUM	0	0	0	0	0	0	0
LOW	0	0	0	0	0	1	0
TOTALS	0	0	0	20	0	1	0

PRIMARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
YELLOW	0	ERR	0	ERR	0	ERR	20	0.97	0	ERR	0	ERR	0	ERR
TOTALS	0		0		0		20		0		0		0	

SECONDARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	0	ERR	0	ERR	0	ERR	4	0.08	0	ERR	1	0.05	0	ERR
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	2	0.18	0	ERR	0	ERR	0	ERR
YELLOW	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
TOTALS	0		0		0		6		0		1		0	

Table 54A. Results for Sample 31, Retroreflective White.

OSHA COLOR SAMPLE NO 31

COLOR NAME	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	0	0	0	0	0	0	0
RED ORANGE	0	0	0	0	0	0	0
ORANGE RED	0	0	0	0	0	0	0
PINK	0	0	0	0	0	0	0
ORANGE	0	0	0	0	0	0	0
GOLD	0	0	0	1	0	0	0
YELLOW	0	0	0	13	0	0	0
YELLOW GREEN	0	0	0	2	0	0	0
TAN	0	1	0	0	0	0	0
OLIVE	0	0	0	3	0	0	0
GREEN	0	0	0	1	0	0	0
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	0	0	1	0	0	0	0
MAGENTA	0	1	0	0	0	0	0
BROWN	0	0	0	0	0	0	0
GRAY	12	13	15	0	15	17	16
BLACK	0	0	0	0	0	0	0
WHITE	8	5	4	0	5	3	4
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	18	15	16	5	15	15	15
MEDIUM	2	5	4	15	5	5	5
LOW	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	1	0	0	6	0	0	0
MEDIUM	0	1	0	9	0	0	0
LOW	2	2	1	5	1	1	1
TOTALS	3	3	1	20	1	1	1

PRIMARY HUES	CW FREQ	CW AVG%	HPS FREQ	HPS AVG%	HPSMH FREQ	HPSMH AVG%	LPS FREQ	LPS AVG%	MER FREQ	MER AVG%	MH FREQ	MH AVG%	TUN FREQ	TUN AVG%
RED	0	ERR	1	0.60	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
BLUE	0	ERR	0	ERR	1	0.60	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	2	0.75	0	ERR	0	ERR	0	ERR
YELLOW	0	ERR	1	0.80	0	ERR	18	0.94	0	ERR	0	ERR	0	ERR
TOTALS	0		2		1		20		0		0		0	

SECONDARY HUES	CW FREQ	CW AVG%	HPS FREQ	HPS AVG%	HPSMH FREQ	HPSMH AVG%	LPS FREQ	LPS AVG%	MER FREQ	MER AVG%	MH FREQ	MH AVG%	TUN FREQ	TUN AVG%
RED	0	ERR	1	0.05	1	0.40	3	0.08	0	ERR	0	ERR	0	ERR
BLUE	2	0.03	1	0.40	0	ERR	0	ERR	1	0.10	1	0.10	0	ERR
GREEN	0	ERR	1	0.20	0	ERR	8	0.09	0	ERR	0	ERR	0	ERR
YELLOW	0	ERR	0	ERR	0	ERR	2	0.25	0	ERR	0	ERR	1	0.05
TOTALS	2		3		1		13		1		1		1	

Table 55A. Results for Sample 32, Ordinary White.

OSHA COLOR SAMPLE NO. 32

COLOR NAME	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	0	0	0	0	0	0	0
RED ORANGE	0	0	0	0	0	0	0
ORANGE RED	0	0	0	0	0	0	0
PINK	0	0	0	0	0	0	0
ORANGE	0	0	0	0	0	0	0
GOLD	0	0	0	0	0	0	0
YELLOW	0	0	0	20	0	0	0
YELLOW GREEN	0	0	0	0	0	0	0
TAN	0	0	0	0	0	0	0
OLIVE	0	0	0	0	0	0	0
GREEN	0	0	0	0	0	0	0
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	0	0	0	0	0	0	0
MAGENTA	0	0	0	0	0	0	0
BROWN	0	0	0	0	0	0	0
GRAY	1	1	0	0	1	0	0
BLACK	0	0	0	0	0	0	0
WHITE	19	19	20	0	19	20	20
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	20	20	20	13	19	20	20
MEDIUM	0	0	0	7	1	0	0
LOW	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	0	1	0	14	0	0	0
MEDIUM	0	0	0	6	0	0	0
LOW	0	2	0	0	0	0	1
TOTALS	0	3	0	20	0	0	1

PRIMARY HUES	CW FREQ	CW AVG%	HPS FREQ	HPS AVG%	HPSMH FREQ	HPSMH AVG%	LPS FREQ	LPS AVG%	MER FREQ	MER AVG%	MH FREQ	MH AVG%	TUN FREQ	TUN AVG%
RED	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
YELLOW	0	ERR	0	ERR	0	ERR	20	0.98	0	ERR	0	ERR	0	ERR
TOTALS	0		0		0		20		0		0		0	

SECONDARY HUES	CW FREQ	CW AVG%	HPS FREQ	HPS AVG%	HPSMH FREQ	HPSMH AVG%	LPS FREQ	LPS AVG%	MER FREQ	MER AVG%	MH FREQ	MH AVG%	TUN FREQ	TUN AVG%
RED	0	ERR	0	ERR	0	ERR	4	0.06	0	ERR	0	ERR	0	ERR
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	2	0.05	0	ERR	0	ERR	0	ERR
YELLOW	0	ERR	3	0.05	0	ERR	0	ERR	0	ERR	0	ERR	1	0.05
TOTALS	0		3		0		6		0		0		1	

Table 56A. Results for Sample 41, Retroreflective White.

OSHA COLOR SAMPLE NO. 41

COLOR NAME	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	0	0	0	0	0	0	0
RED ORANGE	0	0	0	0	0	0	0
ORANGE RED	0	0	0	0	0	0	0
PINK	0	0	1	0	0	0	0
ORANGE	0	0	0	0	0	0	0
GOLD	0	0	0	1	0	0	0
YELLOW	0	0	0	18	0	0	0
YELLOW GREEN	0	0	0	1	0	0	0
TAN	0	0	0	0	0	0	0
OLIVE	0	0	0	0	0	0	0
GREEN	0	0	0	0	0	0	0
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	0	0	0	0	0	0	0
MAGENTA	0	0	0	0	0	0	0
BROWN	0	0	0	0	0	0	0
GRAY	11	6	4	0	6	10	9
BLACK	0	0	0	0	0	0	0
WHITE	9	14	15	0	14	10	11
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	18	18	19	7	19	18	18
MEDIUM	2	2	1	13	1	2	2
LOW	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	0	0	1	8	0	0	0
MEDIUM	0	0	0	9	0	0	0
LOW	2	1	0	3	2	2	1
TOTALS	2	1	1	20	2	2	1

PRIMARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
YELLOW	0	ERR	0	ERR	0	ERR	20	0.95	0	ERR	0	ERR	0	ERR
TOTALS	0		0		0		20		0		0		0	

SECONDARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	0	ERR	0	ERR	1	0.10	4	0.06	0	ERR	0	ERR	0	ERR
BLUE	2	0.05	0	ERR	0	ERR	0	ERR	2	0.02	2	0.05	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	9	0.08	0	ERR	0	ERR	0	ERR
YELLOW	0	ERR	1	0.10	0	ERR	0	ERR	0	ERR	0	ERR	1	0.05
TOTALS	2		1		1		13		2		2		1	

Table 57A. Results for Sample 9, ANSI Gray.

OSHA COLOR SAMPLE NO. 9

COLOR NAME	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	0	0	0	0	0	0	0
RED ORANGE	0	0	0	0	0	0	0
ORANGE RED	0	0	0	0	0	0	0
PINK	0	0	0	0	0	0	0
ORANGE	0	0	0	0	0	0	0
GOLD	0	0	0	1	0	0	0
YELLOW	0	0	0	3	0	0	0
YELLOW GREEN	0	0	0	1	0	0	0
TAN	0	1	0	3	0	0	0
OLIVE	0	0	0	9	0	0	0
GREEN	0	0	0	1	0	0	0
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	1	0	1	0	0	0	1
MAGENTA	0	0	0	0	0	0	0
BROWN	0	0	0	0	0	0	0
GRAY	19	19	19	2	20	20	19
BLACK	0	0	0	0	0	0	0
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	5	8	7	3	3	5	2
MEDIUM	13	12	13	14	16	15	18
LOW	2	0	0	3	1	0	0
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	0	0	0	0	0	0	0
MEDIUM	0	0	0	5	0	0	0
LOW	2	2	1	14	3	1	1
TOTALS	2	2	1	19	3	1	1

PRIMARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	1	0.50	0	ERR	1	0.60	1	0.60	0	ERR	0	ERR	1	0.50
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	6	0.83	0	ERR	0	ERR	0	ERR
YELLOW	0	ERR	1	0.70	0	ERR	11	0.75	0	ERR	0	ERR	0	ERR
TOTALS	1		1		1		18		0		0		1	

SECONDARY HUES	CW		HPS		HPSMH		LPS		MER		MH		TUN	
	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%	FREQ	AVG%
RED	0	ERR	1	0.30	0	ERR	3	0.28	0	ERR	0	ERR	0	ERR
BLUE	2	0.28	0	ERR	1	0.40	0	ERR	2	0.08	1	0.05	1	0.50
GREEN	0	ERR	0	ERR	0	ERR	9	0.22	1	0.02	0	ERR	0	ERR
YELLOW	0	ERR	1	0.05	0	ERR	6	0.23	0	ERR	0	ERR	0	ERR
TOTALS	2		2		1		18		3		1		1	

Table 58A. Results for Sample 8, ANSI Black.

OSHA COLOR SAMPLE NO. 8

COLOR NAME	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
RED	0	0	0	0	0	0	0
RED ORANGE	0	0	0	0	0	0	0
ORANGE RED	0	0	0	0	0	0	0
PINK	0	0	0	0	0	0	0
ORANGE	0	0	0	1	0	0	0
GOLD	0	0	0	0	0	0	0
YELLOW	0	0	0	0	0	0	0
YELLOW GREEN	0	0	0	0	0	0	0
TAN	0	0	0	0	0	0	0
OLIVE	0	0	0	0	0	0	0
GREEN	0	0	0	0	0	0	0
BLUE GREEN	0	0	0	0	0	0	0
BLUE	0	0	0	0	0	0	0
PURPLE	0	0	0	0	0	0	0
MAGENTA	0	0	0	0	0	0	0
BROWN	0	0	0	1	0	0	0
GRAY	0	0	2	2	2	0	0
BLACK	20	20	18	16	18	20	20
WHITE	0	0	0	0	0	0	0
TOTALS	20	20	20	20	20	20	20

LIGHTNESS	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	0	0	0	0	0	0	0
MEDIUM	0	0	0	0	0	0	0
LOW	20	20	20	20	20	20	20
TOTALS	20	20	20	20	20	20	20

SATURATION	FREQUENCY CW	HPS	HPSMH	LPS	MER	MH	TUN
HIGH	0	0	0	0	0	0	0
MEDIUM	0	1	0	0	1	0	0
LOW	0	0	0	3	0	1	0
TOTALS	0	1	0	3	1	1	0

PRIMARY HUES	CW FREQ	CW AVG%	HPS FREQ	HPS AVG%	HPSMH FREQ	HPSMH AVG%	LPS FREQ	LPS AVG%	MER FREQ	MER AVG%	MH FREQ	MH AVG%	TUN FREQ	TUN AVG%
RED	0	ERR	0	ERR	0	ERR	1	0.95	0	ERR	0	ERR	0	ERR
BLUE	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
YELLOW	0	ERR	0	ERR	0	ERR	1	0.85	0	ERR	0	ERR	0	ERR
TOTALS	0		0		0		2		0		0		0	

SECONDARY HUES	CW FREQ	CW AVG%	HPS FREQ	HPS AVG%	HPSMH FREQ	HPSMH AVG%	LPS FREQ	LPS AVG%	MER FREQ	MER AVG%	MH FREQ	MH AVG%	TUN FREQ	TUN AVG%
RED	0	ERR	0	ERR	0	ERR	1	0.15	0	ERR	0	ERR	0	ERR
BLUE	0	ERR	1	0.10	0	ERR	1	0.10	1	0.10	1	0.10	0	ERR
GREEN	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR	0	ERR
YELLOW	0	ERR	0	ERR	0	ERR	1	0.05	0	ERR	0	ERR	0	ERR
TOTALS	0		1		0		3		1		1		0	

Appendix B. Additional Tables of Results

Table 1B. Rank Ordering of Samples for Each Light Source.

RANKS

RED

	TUN	CW	HPS	HPS MH	MH	MER	LPS
1	58	33	33	33	33	57	57
2	33	57	57	57	57	45	58
3	57	58	58	58	58	12	45,47

ORANGE

	TUN	CW	HPS	HPS MH	MH	MER	LPS
1	42,16,56	15	56,16	15,16,56	42,48	48,56,15	48
2	48,35,15, 18	16	-	-	16	-	42
3		42,56	15	-	-	-	15
		48	42,48	42,48	56,15	16	46

YELLOW

	TUN	CW	HPS	HPS MH	MH	MER	LPS
1	4,22	22	22,4	22	22	21,22	4,22,20
2	-	4	-	4	4	-	-
3	20	36	21,20	21,36	36,20	36	-
4	-	-	-	-	-	23	21,49

GREEN

	TUN	CW	HPS	HPS MH	MH	MER	LPS
1	23	55	23	23	23	39,55	23
2	51	23	51	51	3	-	X
3	24	39,51	24	24	24	26,25,3	X

Table 1B. Continued

BLUE

	TUN	CW	HPS	HPS MH	MH	MER	LPS
1	2,27	2,27	28,52	2,27	2,27	52	28
	28,52	28,52	-	28,52	28,52	-	(27)
2	-	-	-	-	-	28	(40)
3	-	-	2,27,40,54	-	-	27	-

PURPLE/MAGENTA

	TUN	CW	HPS	HPS MH	MH	MER	LPS
P-1	1	1	1	1	1	1	X
M-2	53	53	53	53	53	53	X
3	-	-	-	-	-	-	-

BROWN

	TUN	CW	HPS	HPS MH	MH	MER	LPS
1	38	7	38	38	7	38	7
2	7	38	7	7	38	7	38

WHITE

	TUN	CW	HPS	HPS MH	MH	MER	LPS
1	10	10	10	10	32	10	X
2	32	32	32	32	10	32	X
3	41	-	41	41	41	41	X

GRAY

	TUN	CW	HPS	HPS MH	MH	MER	LPS
1	9	9	9	9	9	9	X

BLACK

	TUN	CW	HPS	HPS MH	MH	MER	LPS
1	8	8	8	8	8	8	8y

Table 2B. CIE Specifications for ANSI and Best Colors in Y,x,y, and L*a*b* Coordinates

SAMPLE	LIGHT	M/C	Y	x	y	L*	a*	b*
ANSI RED	TUN	M	19.4	0.654	0.333	51.2	56.96	54.31
ANSI RED	CWF	C	12.7	0.590	0.360	42.3	45.57	39.04
ANSI RED	MER	C	6.3	0.459	0.423	30.1	17.58	17.84
ANSI RED	MH	C	12.3	0.580	0.374	41.6	41.63	37.74
ANSI RED	HPSMH	C	14.9	0.602	0.372	45.5	37.17	44.28
ANSI RED	HPS	C	18.6	0.622	0.371	50.2	28.82	51.87
ANSI RED	LPS	C	17.2	0.574	0.425	48.5	1.94	38.10
ANSI RED	D-65	C	12.5	0.585	0.331	41.9	57.44	38.42
ANSI RED	A	C	18.1	0.646	0.334	49.6	58.58	51.60
ANSI RED	B	C	14.0	0.608	0.333	44.2	58.54	42.37
ANSI RED	C	C	12.6	0.584	0.327	42.2	55.32	38.87
ANSI ORANGE	TUN	M	41.0	0.602	0.391	70.2	38.47	88.84
ANSI ORANGE	CWF	C	36.5	0.545	0.441	66.9	27.11	88.76
ANSI ORANGE	MER	C	33.3	0.465	0.520	64.4	7.10	87.95
ANSI ORANGE	MH	C	37.2	0.543	0.444	67.5	28.58	88.52
ANSI ORANGE	HPSMH	C	42.2	0.563	0.429	71.0	23.65	94.02
ANSI ORANGE	HPS	C	49.3	0.582	0.415	75.6	14.69	97.88
ANSI ORANGE	LPS	C	56.7	0.571	0.428	80.0	1.04	72.98
ANSI ORANGE	D-65	C	31.1	0.547	0.423	62.6	36.65	80.65
ANSI ORANGE	A	C	39.2	0.594	0.397	68.9	39.84	88.10
ANSI ORANGE	B	C	33.6	0.563	0.415	64.6	38.27	83.65
ANSI ORANGE	C	C	31.5	0.548	0.420	62.9	33.85	81.53
ANSI YELLOW	TUN	M	69.2	0.541	0.442	86.6	10.07	82.56
ANSI YELLOW	CWF	C	67.9	0.483	0.489	86.0	-0.80	95.66
ANSI YELLOW	MER	C	69.3	0.427	0.554	86.6	-12.91	108.43
ANSI YELLOW	MH	C	67.8	0.484	0.488	85.9	2.81	91.53
ANSI YELLOW	HPSMH	C	70.5	0.519	0.464	87.2	3.69	93.00
ANSI YELLOW	HPS	C	74.3	0.558	0.435	89.0	3.07	89.78
ANSI YELLOW	LPS	C	77.4	0.569	0.430	90.5	0.24	70.00
ANSI YELLOW	D-65	C	62.5	0.455	0.486	83.2	-2.14	88.46
ANSI YELLOW	A	C	68.1	0.527	0.450	86.1	9.59	84.78
ANSI YELLOW	B	C	64.3	0.479	0.475	84.1	2.51	88.62
ANSI YELLOW	C	C	62.6	0.458	0.481	83.2	-4.05	89.53
ANSI GREEN	TUN	M	8.9	0.302	0.549	35.8	-48.24	-1.47
ANSI GREEN	CWF	C	9.4	0.284	0.524	36.7	-41.57	13.87
ANSI GREEN	MER	C	9.2	0.332	0.576	36.5	-26.92	32.14
ANSI GREEN	MH	C	9.5	0.276	0.537	36.9	-43.65	10.99
ANSI GREEN	HPSMH	C	7.8	0.327	0.517	33.5	-35.55	4.30
ANSI GREEN	HPS	C	5.4	0.437	0.472	27.7	-18.24	-12.93
ANSI GREEN	LPS	C	3.8	0.557	0.434	23.0	-1.74	-16.64
ANSI GREEN	D-65	C	12.0	0.204	0.491	41.2	-59.33	16.86
ANSI GREEN	A	C	9.4	0.281	0.543	36.8	-50.57	2.68
ANSI GREEN	B	C	11.1	0.224	0.501	39.8	-56.11	13.18
ANSI GREEN	C	C	11.7	0.206	0.476	40.8	-58.39	16.89

Table 2B Continued

ANSI BLUE	TUN	M	6.2	0.274	0.343	29.9	-22.28	-49.81
ANSI BLUE	CWF	C	6.4	0.214	0.228	30.3	-3.69	-47.48
ANSI BLUE	MER	C	5.4	0.229	0.213	27.8	15.85	-47.81
ANSI BLUE	MH	C	6.6	0.217	0.265	30.8	-11.31	-45.53
ANSI BLUE	HPSMH	C	5.5	0.258	0.284	28.1	-11.31	-50.46
ANSI BLUE	HPS	C	4.0	0.380	0.344	23.7	-7.23	-60.69
ANSI BLUE	LPS	C	3.2	0.549	0.421	20.7	-0.77	-56.97
ANSI BLUE	D-65	C	8.9	0.171	0.194	35.8	-5.82	-39.56
ANSI BLUE	A	C	6.6	0.244	0.310	31.0	-21.28	-48.00
ANSI BLUE	B	C	8.2	0.183	0.215	34.3	-10.58	-42.21
ANSI BLUE	C	C	8.8	0.170	0.182	35.7	-3.32	-39.72
ANSI PURPLE	TUN	M	17.3	0.554	0.340	48.6	34.79	-7.30
ANSI PURPLE	CWF	C	13.3	0.385	0.297	43.2	23.56	-21.38
ANSI PURPLE	MER	C	11.0	0.305	0.288	39.6	18.96	-31.63
ANSI PURPLE	MH	C	12.8	0.391	0.318	42.5	20.33	-21.65
ANSI PURPLE	HPSMH	C	13.2	0.452	0.341	43.1	17.12	-20.26
ANSI PURPLE	HPS	C	13.8	0.550	0.380	44.0	12.42	-16.18
ANSI PURPLE	LPS	C	11.0	0.567	0.425	39.6	0.52	-21.34
ANSI PURPLE	D-65	C	14.6	0.340	0.246	45.0	34.92	-16.35
ANSI PURPLE	A	C	16.7	0.520	0.330	47.9	35.06	-9.39
ANSI PURPLE	B	C	15.1	0.389	0.271	45.8	35.02	-14.70
ANSI PURPLE	C	C	14.7	0.336	0.236	45.2	35.12	-16.31
ANSI BROWN	TUN	M	7.1	0.574	0.400	32.0	16.10	30.75
ANSI BROWN	CWF	C	6.7	0.507	0.429	31.0	12.08	30.44
ANSI BROWN	MER	C	6.4	0.444	0.486	30.3	5.42	30.15
ANSI BROWN	MH	C	6.8	0.511	0.436	31.4	13.12	31.20
ANSI BROWN	HPSMH	C	7.6	0.539	0.429	33.2	10.25	34.08
ANSI BROWN	HPS	C	8.8	0.568	0.421	35.6	5.28	36.68
ANSI BROWN	LPS	C	10.2	0.570	0.429	38.1	0.41	32.39
ANSI BROWN	D-65	C	5.7	0.479	0.398	28.7	15.85	26.27
ANSI BROWN	A	C	6.8	0.561	0.403	31.4	16.83	30.16
ANSI BROWN	B	C	6.1	0.506	0.401	29.6	16.37	27.69
ANSI BROWN	C	C	5.8	0.477	0.392	28.8	14.43	26.66
ANSI WHITE	TUN	M	81.5	0.479	0.417	92.3	0.82	2.26
ANSI WHITE	CWF	C	81.3	0.387	0.389	92.3	0.08	2.74
ANSI WHITE	MER	C	81.3	0.349	0.416	92.2	-0.72	3.66
ANSI WHITE	MH	C	81.3	0.396	0.407	92.3	0.08	3.17
ANSI WHITE	HPSMH	C	81.5	0.450	0.412	92.4	0.22	3.18
ANSI WHITE	HPS	C	81.8	0.530	0.421	92.5	0.29	2.53
ANSI WHITE	LPS	C	82.1	0.567	0.429	92.6	0.02	3.79
ANSI WHITE	D-65	C	81.1	0.317	0.334	92.2	-0.15	2.47
ANSI WHITE	A	C	81.4	0.451	0.409	92.3	0.75	2.35
ANSI WHITE	B	C	81.2	0.353	0.356	92.2	0.21	2.41
ANSI WHITE	C	C	81.1	0.314	0.321	92.2	-0.22	2.44

Table 2B Continued

ANSI GRAY	TUN	M	19.2	0.476	0.418	50.9	-0.48	0.66
ANSI GRAY	CWF	C	19.2	0.384	0.387	51.0	-0.32	0.78
ANSI GRAY	MER	C	19.3	0.347	0.412	51.1	-0.17	0.92
ANSI GRAY	MH	C	19.2	0.393	0.405	51.0	-0.30	1.05
ANSI GRAY	HPSMH	C	19.3	0.448	0.412	51.0	-0.27	1.03
ANSI GRAY	HPS	C	19.3	0.529	0.422	51.0	-0.24	0.85
ANSI GRAY	LPS	C	19.3	0.567	0.429	51.1	-0.01	1.36
ANSI GRAY	D-65	C	19.2	0.314	0.332	50.9	-0.59	0.84
ANSI GRAY	A	C	19.2	0.447	0.410	50.9	-0.48	0.72
ANSI GRAY	B	C	19.2	0.349	0.355	50.9	-0.54	0.81
ANSI GRAY	C	C	19.2	0.311	0.320	50.9	-0.62	0.84
ANSI BLACK	TUN	M	1.6	0.494	0.423	13.1	0.82	4.52
ANSI BLACK	CWF	C	1.6	0.408	0.414	13.0	-0.37	5.30
ANSI BLACK	MER	C	1.6	0.368	0.450	13.0	-1.30	6.16
ANSI BLACK	MH	C	1.6	0.415	0.430	13.0	-0.32	5.53
ANSI BLACK	HPSMH	C	1.6	0.466	0.428	13.1	-0.03	5.53
ANSI BLACK	HPS	C	1.6	0.537	0.425	13.2	-0.22	4.79
ANSI BLACK	LPS	C	1.6	0.568	0.429	13.4	0.02	5.11
ANSI BLACK	D-65	C	1.5	0.342	0.368	12.8	-0.95	5.07
ANSI BLACK	A	C	1.6	0.469	0.420	13.0	0.68	4.71
ANSI BLACK	B	C	1.5	0.378	0.384	12.9	-0.34	5.03
ANSI BLACK	C	C	1.5	0.340	0.356	12.8	-1.13	5.14
BEST RED - F	TUN	M	16.7	0.647	0.325	47.8	55.66	34.21
BEST RED - F	CWF	M	10.9	0.572	0.341	39.4	45.58	23.63
BEST RED - F	MER	M	10.5	0.537	0.359	38.8	49.61	20.32
BEST RED - F	MH	M	12.8	0.579	0.348	42.5	49.09	25.92
BEST RED - F	HPSMH	M	12.1	0.596	0.351	41.4	39.17	24.34
BEST RED - F	HPS	M	12.1	0.629	0.354	41.4	30.32	25.93
BEST RED - F	LPS	M	8.8	0.616	0.381	35.7	15.44	12.21
BEST ORANGE - F	TUN	M	57.9	0.637	0.354	80.7	67.61	90.95
BEST ORANGE - F	CWF	M	50.6	0.609	0.372	76.4	72.12	89.65
BEST ORANGE - F	MER	M	51.9	0.587	0.387	77.2	86.99	83.89
BEST ORANGE - F	MH	M	66.6	0.604	0.379	85.3	78.02	96.04
BEST ORANGE - F	HPSMH	M	58.5	0.611	0.377	81	59.22	92.48
BEST ORANGE - F	HPS	M	67.7	0.622	0.374	85.9	42.82	97.03
BEST ORANGE - F	LPS	M	62.8	0.596	0.401	83.3	16.97	12.4

Table 2B Continued

BEST YELLOW - O	TUN	M	70.0	0.552	0.433	87.0	16.41	87.01
BEST YELLOW - O	CWF	C	68.6	0.495	0.480	86.3	5.43	98.76
BEST YELLOW - O	MER	C	68.6	0.439	0.544	86.3	-6.40	110.48
BEST YELLOW - O	MH	C	68.1	0.497	0.478	86.1	9.91	93.40
BEST YELLOW - O	HPSMH	C	72.7	0.527	0.457	88.3	8.19	96.76
BEST YELLOW - O	HPS	C	79.2	0.560	0.435	91.3	3.71	97.82
BEST YELLOW - O	LPS	C	82.7	0.570	0.429	92.9	0.32	73.45
BEST YELLOW - O	D-65	C	61.0	0.473	0.471	82.4	7.97	88.62
BEST YELLOW - O	A	C	68.5	0.540	0.440	86.3	16.62	88.35
BEST YELLOW - O	B	C	63.4	0.495	0.462	83.7	11.47	89.82
BEST YELLOW - O	C	C	61.3	0.476	0.467	82.5	5.52	89.83
BEST GREEN - F	TUN	M	16.1	0.316	0.647	47.1	-67.35	42.87
BEST GREEN - F	CWF	M	21.9	0.300	0.653	53.9	-68.32	61.31
BEST GREEN - F	MER	M	21.1	0.309	0.648	53	-51.59	61.91
BEST GREEN - F	MH	M	23.4	0.300	0.658	55.5	-68.8	61.5
BEST GREEN - F	HPSMH	M	16.6	0.324	0.634	47.8	-61.4	46.72
BEST GREEN - F	HPS	M	9.7	0.413	0.565	37.3	-38.05	28.35
BEST GREEN - F	LPS	M	4	0.561	0.433	23.6	-1.14	-5.1
BEST GREEN - O	TUN	M	21.6	0.258	0.560	53.6	-78.5	-9.47
BEST GREEN - O	CWF	C	24.3	0.258	0.507	56.3	-62.19	10.64
BEST GREEN - O	MER	C	26.5	0.315	0.557	58.5	-40.12	35.2
BEST GREEN - O	MH	C	23.7	0.252	0.521	55.8	-64.46	6.35
BEST GREEN - O	MIX	C	19	0.289	0.514	50.6	-57.04	-3.43
BEST GREEN - O	HPS	C	12.2	0.385	0.493	41.5	-36.45	-27.23
BEST GREEN - O	LPS	C	5.7	0.544	0.439	28.7	-4.28	-41.68
BEST GREEN - O	D65	C	29.8	0.189	0.452	61.4	-79.75	13.35
BEST GREEN - O	A	C	23.1	0.243	0.543	55.2	-79.49	-4.32
BEST GREEN - O	B	C	27.6	0.203	0.471	59.6	-78.93	8.78
BEST GREEN - O	C	C	29.2	0.190	0.436	61	-78.38	13.36
BEST BLUE - O	TUN	M	11.4	0.172	0.345	40.3	-58.57	-73.30
BEST BLUE - O	CWF	C	11.4	0.159	0.205	40.2	-18.97	-70.33
BEST BLUE - O	MER	C	8.0	0.189	0.164	34.0	23.68	-75.34
BEST BLUE - O	MH	C	12.1	0.153	0.248	41.4	-34.95	-67.06
BEST BLUE - O	HPSMH	C	8.7	0.164	0.251	35.4	-34.77	-77.87
BEST BLUE - O	HPS	C	3.9	0.214	0.270	23.3	-24.10	-102.52
BEST BLUE - O	LPS	C	1.4	0.466	0.393	12.2	-4.32	-109.04
BEST BLUE - O	D-65	C	19.6	0.140	0.197	51.4	-26.78	-53.11
BEST BLUE - O	A	C	12.8	0.161	0.309	42.4	-55.56	-69.39
BEST BLUE - O	B	C	17.3	0.143	0.214	48.6	-34.20	-58.16
BEST BLUE - O	C	C	19.2	0.141	0.182	50.9	-21.79	-53.79

Table 3B. CIELAB and Psychophysical Responses

Sample	L*	a*	b*	Source	Name	N	LT	SAT	HUE1	%	HUE2	%
O PURPLE 1	43.2	23.56	-21.38	CWF	P	20	M	M	R/B	.55/.66	R/B	.34/.45
O PURPLE 1	44.0	12.42	-16.18	HPS	P	19	M	M	R	0.61	B	0.39
O PURPLE 1	43.1	17.12	-20.26	HPSMH	P	20	M	M	B	0.59	R	0.41
O PURPLE 1	39.6	0.52	-21.34	LPS	GY	7	M	L	G	0.85	Y	0.19
O PURPLE 1	39.6	18.96	-31.63	MER	P	20	M	M	B	0.65	R	0.35
O PURPLE 1	42.5	20.33	-21.65	MH	P	20	M	M	B	0.60	R	0.40
O PURPLE 1	48.6	34.79	-7.30	TUN	P	15	M	M	R	0.75	B	0.25
O BLUE 2	30.3	-3.69	-47.48	CWF	B	20	M	M	B	0.99	R	0.07
O BLUE 2	23.7	-7.23	-60.69	HPS	B	20	L	M	B	0.98	-	-
O BLUE 2	28.1	-11.31	-50.46	HPSMH	B	20	M	M	B	0.99	R	0.08
O BLUE 2	20.7	-0.77	-56.97	LPS	GY	12	L	L	R	0.80	Y	0.16
O BLUE 2	27.8	15.85	-47.81	MER	B	12	M/L	M	B	0.83	R	0.19
O BLUE 2	30.8	-11.31	-45.53	MH	B	20	M	M	B	0.98	R	0.08
O BLUE 2	29.9	-22.28	-49.81	TUN	B	20	M	M	B	0.97	G	0.13
O GREEN 3	36.7	-41.57	13.87	CWF	G	11	M	M	G	0.84	B	0.20
O GREEN 3	27.7	-18.24	-12.93	HPS	BG	10	L	M	G	0.81	B	0.26
O GREEN 3	33.5	-35.55	4.30	HPSMH	G	10	M	M	G	0.84	B	0.22
O GREEN 3	23.0	-1.74	-16.64	LPS	GY	13	L	-	-	-	-	-
O GREEN 3	36.5	-26.92	32.14	MER	G	17	M/L	L	G	0.89	B/Y	.19/.16
O GREEN 3	36.9	-43.65	10.99	MH	G	12	M	M	G	0.87	B	0.17
O GREEN 3	35.8	-48.24	-1.47	TUN	G	13	M	M	G	1.00	B	0.08
O YELLOW 4	86.0	-0.80	95.66	CWF	Y	15	H	M	Y	0.90	G	0.13
O YELLOW 4	89.0	3.07	89.78	HPS	Y	19	H	H	Y	0.93	G	0.12
O YELLOW 4	87.2	3.69	93.00	HPSMH	Y	17	H	M	Y	0.94	G	0.12
O YELLOW 4	90.5	0.24	70.00	LPS	Y	20	H	H	Y	0.99	G	0.07
O YELLOW 4	86.6	-12.91	108.43	MER	YG	10	H	H	Y	0.85	G	0.18
O YELLOW 4	85.9	2.81	91.53	MH	Y	18	H	H	Y	0.95	G	0.12
O YELLOW 4	86.6	10.07	82.56	TUN	Y	17	M	M	Y	0.94	G	0.08
O ORANGE 5	66.9	27.11	88.76	CWF	O	13	M	M	Y	0.72	R	0.28
O ORANGE 5	75.6	14.69	97.88	HPS	Y	13	M	H/M	Y	0.88	R	0.16
O ORANGE 5	71.0	23.65	94.02	HPSMH	O	10	M	M	Y	0.82	R	0.21
O ORANGE 5	80.0	1.04	72.98	LPS	Y	20	M	H	Y	0.96	R	0.06
O ORANGE 5	64.4	7.10	87.95	MER	Y	12	M	M	Y	0.93	G	0.13
O ORANGE 5	67.5	28.58	88.52	MH	O	11	M	M	Y	0.74	R	0.28
O ORANGE 5	70.2	38.47	88.84	TUN	O	17	M	M	Y	0.76	R	0.24
O RED 6	42.3	45.57	39.04	CWF	R	11	M	M	R	0.85	Y	0.18
O RED 6	50.2	28.82	51.87	HPS	O	13	M	M	R	0.69	Y	0.31
O RED 6	45.5	37.17	44.28	HPSMH	O	9	M	M	R	0.74	Y	0.26
O RED 6	48.5	1.94	38.10	LPS	OY	8	M	L	Y	0.77	G	0.24
O RED 6	30.1	17.58	17.84	MER	BRN	20	L	L	R	0.82	Y	0.20
O RED 6	41.6	41.63	37.74	MH	RO	7	M	M	R	0.79	Y	0.24
O RED 6	51.2	56.96	54.31	TUN	R	12	M	H	R	0.85	Y	0.17
O BROWN 7	31.0	12.08	30.44	CWF	BRN	20	L	M	R	0.75	Y	0.24
O BROWN 7	35.6	5.28	36.68	HPS	BRN	11	L	M/L	R	0.79	Y	0.25
O BROWN 7	33.2	10.25	34.08	HPSMH	BRN	15	L	M	R	0.79	Y	0.21
O BROWN 7	38.1	0.41	32.39	LPS	BRN	-	M	L	G/Y	.87/.82	Y	0.14
O BROWN 7	30.3	5.42	30.15	MER	BRN	11	L	L	G	0.86	Y	0.10
O BROWN 7	31.4	13.12	31.20	MH	BRN	18	L	L	R	0.76	Y	0.26
O BROWN 7	32.0	16.10	30.75	TUN	BRN	19	L	L	R	0.79	Y	0.20

Table 3B Continued

O BLACK 8	13.0	-0.37	5.30	CWF	BK	20	L	-	-	-	-	-
O BLACK 8	13.2	0.22	4.79	HPS	BK	20	L	-	-	-	-	-
O BLACK 8	13.1	-0.03	5.53	HPSMH	BK	18	L	-	-	-	-	-
O BLACK 8	13.4	0.02	5.11	LPS	BK	16	L	-	-	-	-	-
O BLACK 8	13.0	-1.30	6.16	MER	BK	18	L	-	-	-	-	-
O BLACK 8	13.0	-0.32	5.53	MH	BK	20	L	-	-	-	-	-
O BLACK 8	13.1	0.82	4.52	TUN	BK	20	L	-	-	-	-	-
O GRAY 9	51.0	-0.32	0.78	CWF	GY	19	M	-	-	-	-	-
O GRAY 9	51.0	-0.24	0.85	HPS	GY	19	M	-	-	-	-	-
O GRAY 9	51.0	-0.27	1.03	HPSMH	GY	19	M	-	-	-	-	-
O GRAY 9	51.1	-0.01	1.36	LPS	OV	OV	M	L	Y	0.75	G	0.22
O GRAY 9	51.1	-0.17	0.92	MER	GY	20	M	-	-	-	-	-
O GRAY 9	51.0	-0.30	1.05	MH	GY	20	M	-	-	-	-	-
O GRAY 9	50.9	-0.48	0.66	TUN	GY	19	M	-	-	-	-	-
O WHITE 10	92.3	0.08	2.74	CWF	W	20	H	-	-	-	-	-
O WHITE 10	92.5	0.29	2.53	HPS	W	20	H	-	-	-	-	-
O WHITE 10	92.4	0.22	3.18	HPSMH	W	20	H	-	-	-	-	-
O WHITE 10	92.6	0.02	3.79	LPS	Y	20	H	H	Y	0.97	R	0.08
O WHITE 10	92.2	-0.72	3.66	MERCURY	W	19	H	-	-	-	-	-
O WHITE 10	92.3	0.08	3.17	MH	W	19	H	-	-	-	-	-
O WHITE 10	92.3	0.82	2.26	TUN	W	20	H	-	-	-	-	-
R RED 11	38.1	47.71	36.28	CWF	R	14	M	H/M	R	0.86	Y	0.17
R RED 11	46.6	29.84	52.89	HPS	O	14	M	M	R	0.64	Y	0.36
R RED 11	41.5	38.55	41.06	HPSMH	O	8	M	M	R	0.77	Y	0.24
R RED 11	44.8	2.10	34.67	LPS	OV	7	M	L	Y	0.79	Y/G	.21/.22
R RED 11	23.6	22.10	7.24	MER	BRN	13	L	M	R	0.87	Y	0.16
R RED 11	37.3	43.36	33.45	MH	R	12	M	M	R	0.82	Y	0.18
R RED 11	46.7	55.97	54.11	TUN	R	13	M	H	R	0.87	Y	0.16
O RED 12	50.2	58.58	51.26	CWF	R/RO	6/6	M	H	R	0.78	Y	0.22
O RED 12	61.9	35.50	75.49	HPS	O	18	M	M	R	0.61	Y	0.39
O RED 12	55.6	46.94	58.22	HPSMH	O	12	M	M	R	0.71	Y	0.29
O RED 12	64.2	2.50	52.83	LPS	Y	10	M	M/L	Y	0.87	G	0.14
O RED 12	31.7	29.00	11.96	MER	R	10	L	M	R	0.85	B	0.19
O RED 12	50.4	53.65	48.61	MH	R	8	M	M	R	0.81	Y	0.23
O RED 12	60.1	67.26	74.62	TUN	O	11	M	H	R	0.71	Y	0.29
RF R-ORANGE 13	66.1	83.40	99.66	CWF	O	13	M	H	R	0.68	Y	0.33
RF R-ORANGE 13	64.3	50.50	92.09	HPS	O	12	M	H	R	0.65	Y	0.35
RF R-ORANGE 13	66.7	71.15	97.58	HPSMH	O	9	M	H	R	0.67	Y	0.33
RF R-ORANGE 13	63.9	44.09	49.91	LPS	O	12	M	H	R	0.71	Y	0.29
RF R-ORANGE 13	66.2	106.08	99.89	MER	O	8	M	H	R	0.70	Y	0.30
RF R-ORANGE 13	69.0	89.01	99.55	MH	O	8	M	H	R	0.69	Y	0.32
RF R-ORANGE 13	63.7	67.25	101.06	TUN	O	14	M	H	R	0.63	Y	0.37
F R-ORANGE 14	65.4	78.36	74.14	CWF	O	8	M	H	R	0.73	Y	0.27
F R-ORANGE 14	71.0	48.35	86.53	HPS	O	17	M	H	R	0.61	Y	0.39
F R-ORANGE 14	65.7	63.11	72.78	HPSMH	O	12	M	H	R	0.71	Y	0.29
F R-ORANGE 14	60.2	25.17	18.64	LPS	O	20	M	M	R	0.62	Y	0.38
F R-ORANGE 14	59.6	88.50	57.92	MER	O	9	M	M	R	0.75	Y	0.25
F R-ORANGE 14	67.3	78.43	72.77	MH	O	9	M	H	R	0.68	Y	0.32
F R-ORANGE 14	69.0	73.13	85.85	TUN	O	11	M	H	R	0.70	Y	0.30

Table 3B Continued

RF ORANGE 15	74.7	59.50	105.51	CWF	O	20	M	H	R	0.54	Y	0.46
RF ORANGE 15	73.6	33.20	97.93	HPS	O	19	M	M	Y	0.66	R	0.34
RF ORANGE 15	74.9	47.78	102.19	HPSMH	O	20	M	H	Y	0.68	R	0.32
RF ORANGE 15	70.1	15.75	27.95	LPS	O	17	M	M	Y	0.67	R	0.29
RF ORANGE 15	77.4	82.54	108.75	MER	O	20	M	H	R/Y	.54/.62	R/Y	.38/.46
RF ORANGE 15	81.0	64.88	112.47	MH	O	19	M	H	Y	0.62	R	0.38
RF ORANGE 15	71.5	49.21	104.79	TUN	O	19	M	H	Y	0.63	R	0.37
F ORANGE 16	79.2	57.10	103.21	CWF	O	20	M	H	Y	0.63	R	0.37
F ORANGE 16	87.0	32.10	107.97	HPS	O	20	M	H	Y	0.63	R	0.37
F ORANGE 16	81.5	43.79	102.61	HPSMH	O	20	H	M	Y	0.65	R	0.35
F ORANGE 16	90.9	4.70	25.09	LPS	Y	19	M	H	Y	0.94	R	0.09
F ORANGE 16	78.3	63.07	98.35	MER	O	19	M	H/M	Y	0.66	R	0.34
F ORANGE 16	84.8	57.81	107.51	MH	O	20	H	H	Y	0.68	R	0.32
F ORANGE 16	82.3	57.28	102.01	TUN	O	20	M	M	Y	0.62	R	0.38
R ORANGE 17	41.5	34.97	64.95	CWF	O	14	M	M	R/Y	.76/.67	R/Y	.33/.24
R ORANGE 17	49.7	21.49	74.64	HPS	O	13	M	M	Y	0.67	R	0.33
R ORANGE 17	45.3	28.99	70.33	HPSMH	O	12	M	M	R/Y	.63/.70	R/Y	.31/.37
R ORANGE 17	51.9	1.45	53.06	LPS	GO	8	M	L	Y	0.90	G	0.12
R ORANGE 17	33.9	11.47	53.92	MER	BRN	7	M	M	Y	0.82	R/G	.18/.21
R ORANGE 17	41.7	32.89	64.74	MH	O	13	M	M	R/Y	.68/.64	R	0.36
R ORANGE 17	47.1	43.97	71.09	TUN	O	16	M	M	R	0.64	Y	0.36
O ORANGE 18	71.2	31.17	92.54	CWF	O	13	M	M	Y	0.76	R	0.25
O ORANGE 18	80.8	17.72	106.28	HPS	O	17	M	H/M	Y	0.75	R	0.28
O ORANGE 18	75.8	27.16	98.92	HPSMH	O	13	M	M	Y	0.79	R	0.22
O ORANGE 18	86.2	1.21	77.56	LPS	Y	20	H	H	Y	0.97	R	0.07
O ORANGE 18	67.8	9.52	84.81	MER	Y	12	M	M	Y	0.91	R	0.13
O ORANGE 18	72.0	32.28	92.52	MH	O	18	M	H/M	Y	0.70	R	0.30
O ORANGE 18	75.1	42.49	96.65	TUN	O	19	M	M	Y	0.69	R	0.31
RF YELLOW 19	80.8	-32.04	102.39	CWF	YG	14	H	H	Y	0.81	G	0.19
RF YELLOW 19	73.3	-10.17	79.18	HPS	Y	10	H	H	Y	0.86	G	0.16
RF YELLOW 19	79.3	-26.01	92.11	HPSMH	YG	14	H	M	Y	0.78	G	0.22
RF YELLOW 19	70.0	0.27	6.81	LPS	Y	14	M	M	Y	0.95	G	0.14
RF YELLOW 19	81.5	-32.03	103.82	MER	YG	12	H	H	Y	0.81	G	0.19
RF YELLOW 19	85.8	-32.49	103.84	MH	YG	14	H	H	Y	0.71	G	0.31
RF YELLOW 19	75.3	-17.76	77.21	TUN	YG	12	H	M	Y	0.79	G	0.23
F YELLOW 20	93.6	-16.77	111.86	CWF	YG	12	H	H	Y	0.83	G	0.18
F YELLOW 20	98.1	-2.16	105.22	HPS	Y	18	H	H	Y	0.93	G	0.12
F YELLOW 20	98.0	-10.87	109.52	HPSMH	Y	11	H	H	Y	0.84	G	0.18
F YELLOW 20	99.9	0.19	-8.46	LPS	Y	20	H	H	Y	0.97	G	0.15
F YELLOW 20	98.8	-25.66	124.35	MER	YG	12	H	H	Y	0.81	G	0.19
F YELLOW 20	101.8	-15.17	115.15	MH	Y	11	H	H	Y	0.85	G	0.19
F YELLOW 20	92.9	-4.01	96.78	TUN	Y	14	H	H	Y	0.90	G	0.14
R YELLOW 21	65.0	10.90	88.66	CWF	Y	11	M	M	Y	0.94	R	0.08
R YELLOW 21	71.1	3.50	91.38	HPS	Y	18	M	M	Y	0.95	G	0.12
R YELLOW 21	67.5	10.84	89.80	HPSMH	Y	10	M	M	Y	0.88	R	0.17
R YELLOW 21	72.8	0.33	66.43	LPS	Y	19	M	H/M	Y	0.97	G	0.09
R YELLOW 21	64.7	1.47	95.39	MER	Y	13	M	M	Y	0.96	G	0.08
R YELLOW 21	64.8	14.95	85.83	MH	O	7	M	M	Y	0.85	R	0.22
R YELLOW 21	65.4	19.67	81.16	TUN	O/GO/Y	6	M	M	Y	0.85	R	0.20

Table 3B Continued

O YELLOW 22	85.7	5.55	98.39	CWF	Y	16	H	H	Y	0.94	R/G	.20/.09
O YELLOW 22	90.7	3.77	97.49	HPS	Y	19	H	H	Y	0.94	G	0.11
O YELLOW 22	87.7	8.26	96.43	HPSMH	Y	18	H/M	M	Y	0.94	R	0.09
O YELLOW 22	92.3	0.32	73.18	LPS	Y	20	H	H	Y	0.98	R	0.07
O YELLOW 22	85.7	-6.31	110.03	MER	Y	13	H/M	H	Y	0.92	G	0.13
O YELLOW 22	85.4	10.00	93.07	MH	Y	17	H	H	Y	0.96	R	0.09
O YELLOW 22	86.4	16.54	86.79	TUN	Y	17	H	H	Y	0.94	R	0.12
RF G-YELLOW 23	53.9	-68.32	61.31	CWF	G	14	M	H	G	0.82	Y	0.20
RF G-YELLOW 23	37.3	-38.05	28.35	HPS	G	17	M	M	G	0.91	Y	0.17
RF G-YELLOW 23	47.8	-61.40	46.72	HPSMH	G	16	M	H	G	0.84	Y	0.17
RF G-YELLOW 23	23.6	-1.14	-5.10	LPS	OV	7	M	L	R/G	.80/.86	Y	0.20
RF G-YELLOW 23	53.0	-51.59	61.91	MER	G	13	M	M	G	0.85	Y	0.17
RF G-YELLOW 23	55.5	-68.80	61.50	MH	G	13	M	H	G	0.78	Y	0.24
RF G-YELLOW 23	47.1	-67.35	42.87	TUN	G	20	M	H	G	0.92	Y	0.13
F G-YELLOW 24	74.9	-61.69	88.94	CWF	YG	12	H	H	G	0.77	Y	0.24
F G-YELLOW 24	60.4	-31.73	64.18	HPS	G	13	M	H	G	0.79	Y	0.24
F G-YELLOW 24	68.3	-49.36	73.24	HPSMH	G	11	M	H	G	0.78	Y	0.22
F G-YELLOW 24	57.6	-0.80	-8.45	LPS	OV	7	M	L	Y	0.80	G	0.18
F G-YELLOW 24	80.3	-44.28	100.15	MER	G	10	M	M	G	0.77	Y	0.23
F G-YELLOW 24	77.2	-58.98	81.77	MH	G	12	H	H	G	0.76	Y	0.24
F G-YELLOW 24	68.1	-68.85	67.80	TUN	G	13	M	H/M	G	0.84	Y	0.18
R GREEN 25	26.0	-35.30	-2.17	CWF	G	11	M	M	G	0.85	B	0.20
R GREEN 25	17.3	-18.86	-25.26	HPS	BG	17	L	M	B	0.67	G	0.33
R GREEN 25	22.9	-32.88	-10.01	HPSMH	BG	15	M	M	G	0.77	B	0.27
R GREEN 25	11.0	-2.15	-30.53	LPS	BK	14	L	-	-	-	-	-
R GREEN 25	25.6	-21.02	10.92	MER	G	17	L	M	G	0.92	G	0.12
R GREEN 25	26.1	-38.34	-3.92	MH	BG	12	M	M	G	0.79	G	0.28
R GREEN 25	25.1	-43.83	-13.53	TUN	BG	13	M	M	G	0.74	G	0.28
O GREEN 26	55.8	-61.75	10.86	CWF	G	10	M	M	G	0.83	B	0.19
O GREEN 26	41.1	-36.16	-26.71	HPS	BG	15	M	M	G	0.79	B	0.21
O GREEN 26	50.2	-56.58	-3.12	HPSMH	BG	14	M	M	G	0.78	B	0.24
O GREEN 26	28.5	-4.23	-41.05	LPS	GY	17	L	-	G	0.95	Y	0.20
O GREEN 26	58.0	-39.88	35.32	MER	G	17	M	M	G	0.89	Y	0.11
O GREEN 26	55.3	-63.95	6.58	MH	BG	12	M	M	G	0.78	B	0.25
O GREEN 26	53.2	-77.90	-8.95	TUN	G	11	M	M	G	0.82	B	0.21
R BLUE 27	17.3	6.76	-57.21	CWF	B	20	M	H	B	0.99	R	0.05
R BLUE 27	9.8	-6.34	-72.41	HPS	B	20	L	H	B	0.98	R/G	.10/.08
R BLUE 27	15.1	-6.81	-59.72	HPSMH	B	20	M	H	B	0.99	-	-
R BLUE 27	5.7	-0.80	-69.44	LPS	BK	15	L	L	B	1.00	B	0.05
R BLUE 27	12.3	33.68	-60.39	MER	B	19	L	M	B	0.96	R	0.13
R BLUE 27	18.0	-4.46	-54.23	MH	B	20	M	H	B	0.98	-	-
R BLUE 27	17.2	-19.05	-59.46	TUN	B	20	M	H	B	0.98	G	0.12
O BLUE 28	39.8	-19.18	-69.36	CWF	B	20	M	H	B	0.98	G	0.09
O BLUE 28	23.0	-23.94	-101.34	HPS	B	20	M	H	B	0.98	G	0.08
O BLUE 28	35.0	-34.71	-76.86	HPSMH	B	20	M	H	B	0.97	G	0.09
O BLUE 28	12.0	-4.28	-107.77	LPS	B	14	L	L	B	0.99	B	0.05
O BLUE 28	33.6	22.94	-74.20	MER	B	19	M	M	B	0.97	R	0.1
O BLUE 28	40.9	-34.96	-66.15	MH	B	20	M	H	B	0.96	G	0.13
O BLUE 28	39.9	-58.12	-72.25	TUN	B	20	M	H	B	0.95	G	0.13

Table 3B Continued

RF MAGENTA 29	67.6	72.73	34.08	CWF	PK	15	H	H	R	0.91	B	0.13
RF MAGENTA 29	70.5	41.01	40.43	HPS	PK	9	H	H	R	0.79	Y	0.24
RF MAGENTA 29	69.1	58.30	40.38	HPSMH	PK	13	H	M	R	0.89	Y	0.15
RF MAGENTA 29	70.6	24.46	22.25	LPS	O	20	M	M	Y	0.67	R	0.33
RF MAGENTA 29	67.4	94.57	29.26	MER	PK	17	M	H	R	0.91	B	0.11
RF MAGENTA 29	73.9	77.90	44.26	MH	PK	13	H/M	H	R	0.86	Y	0.18
RF MAGENTA 29	68.3	59.22	42.83	TUN	PK	12	M	M	R	0.83	Y	0.19
F MAGENTA 30	69.5	72.31	-13.24	CWF	PK	13	H	H	R	0.86	B	0.19
F MAGENTA 30	78.1	38.31	2.31	HPS	PK	19	H	M	R	0.94	B	0.09
F MAGENTA 30	74.9	55.86	-3.66	HPSMH	PK	17	H	M	R	0.92	B	0.12
F MAGENTA 30	83.4	6.21	20.64	LPS	Y	17	H	H	Y	0.91	R	0.13
F MAGENTA 30	64.0	86.01	-33.23	MER	PK	12	H	H	R	0.87	B	0.15
F MAGENTA 30	75.2	71.70	-6.06	MH	PK	16	H	H	R	0.88	B	0.17
F MAGENTA 30	75.4	65.03	1.47	TUN	PK	18	H	H/M	R	0.92	B	0.14
R WHITE 31	62.3	-0.67	5.26	CWF	GY	12	H	L	-	-	-	-
R WHITE 31	62.4	0.45	3.87	HPS	GY	13	H	L	-	-	-	-
R WHITE 31	62.3	-0.17	5.41	HPSMH	GY	15	H	-	-	-	-	-
R WHITE 31	62.3	0.01	4.89	LPS	Y	13	M	M	Y	0.94	G	0.09
R WHITE 31	62.2	-2.18	7.11	MER	GY	15	H	-	-	-	-	-
R WHITE 31	62.3	-0.75	5.59	MH	GY	17	H	-	-	-	-	-
R WHITE 31	62.6	1.48	4.10	TUN	GY	16	H	-	-	-	-	-
O WHITE 32	93.8	-0.63	2.69	CWF	W	19	H	-	-	-	-	-
O WHITE 32	93.8	0.03	1.88	HPS	W	19	H	-	-	-	-	-
O WHITE 32	93.8	-0.35	3.02	HPSMH	W	20	H	-	-	-	-	-
O WHITE 32	93.8	-0.01	3.37	LPS	Y	20	H	H	Y	0.98	-	-
O WHITE 32	93.8	-1.36	4.02	MER	W	19	H	-	-	-	-	-
O WHITE 32	93.8	-0.68	3.17	MH	W	20	H	-	-	-	-	-
O WHITE 32	93.8	0.17	1.89	TUN	W	20	H	-	-	-	-	-
R DK RED 33	32.1	52.03	51.96	CWF	R	20	M	H	R	0.95	Y	0.08
R DK RED 33	38.1	35.06	60.2	HPS	R	18	M	M	R	0.93	Y	0.08
R DK RED 33	33.3	43.44	53.37	HPSMH	R	29	M	H	R	0.94	Y	0.10
R DK RED 33	24.6	3.07	29.31	LPS	BRN	13	L	L	R	0.85	Y	0.17
R DK RED 33	14.4	23.65	23.14	MER	BRN	9	L	M	R	0.88	Y	0.13
R DK RED 33	29.1	48.23	46.4	MH	R	20	L	H	R	0.95	B	0.12
R DK RED 33	44.1	63.02	70.61	TUN	R	19	M	H	R	0.96	Y	0.09
R RED 34	39.3	43.25	41.29	CWF	R	9	M	M	R	0.81	Y	0.21
R RED 34	47.7	26.3	56.16	HPS	O	12	M	M	R	0.66	Y	0.34
R RED 34	43.1	34.96	45.65	HPSMH	O	10	M	M	R	0.74	Y	0.26
R RED 34	48.8	1.74	40.44	LPS	OY	7	M	L	Y	0.82	G	0.17
R RED 34	28.6	18.33	20.12	MER	BRN	20	L	L	R	0.83	Y	0.18
R RED 34	39.3	39.92	38.87	MH	R	8	M	M	R	0.80	Y	0.23
R RED 34	47.1	52.61	56.12	TUN	R	12	M	H	R	0.87	Y	0.15
R ORANGE 35	57.7	34.75	72.75	CWF	O	13	M	M	Y	0.70	R	0.31
R ORANGE 35	66.9	21.17	84.04	HPS	O	16	M	M	Y	0.69	R	0.31
R ORANGE 35	62.4	29.35	78.79	HPSMH	O	12	M	M	Y	0.78	R	0.22
R ORANGE 35	73.2	1.42	66.06	LPS	Y	19	M	H/M	Y	0.96	G	0.11
R ORANGE 35	53.1	8.66	67.17	MER	OY	7	M	L	Y	0.84	G	0.18
R ORANGE 35	58.9	33.69	73.09	MH	O	16	M	M	Y	0.78	R	0.24
R ORANGE 35	62.5	44.71	76.86	TUN	O	19	M	M	R	0.61	Y	0.39

Table 3B Continued

R YELLOW 36	71.4	8.62	103.15	CWF	Y	12	M	M	Y	0.91	G	0.10
R YELLOW 36	76.4	5.3	103.04	WPS	Y	13	M	M	Y	0.89	G	0.19
R YELLOW 36	73.5	10.09	103.61	WPSMH	Y	10	M	M	Y	0.90	R	0.14
R YELLOW 36	78.5	0.44	72.84	LPS	Y	17	M	M	Y	0.96	G	0.09
R YELLOW 36	72.6	-7.24	111.25	MER	Y	9	M	M	Y	0.85	G	0.18
R YELLOW 36	71.4	12.31	100.76	MH	Y	11	M	M	Y	0.88	G	0.13
R YELLOW 36	72	19.37	94.16	TUN	Y	10	M	M	Y	0.88	R	0.12
R GOLD 37	64.8	4.70	51.00	CWF	T	7	M	M/L	Y	0.88	G	0.15
R GOLD 37	68.4	3.32	54.97	WPS	Y	12	M	M	Y	0.90	G	0.09
R GOLD 37	66.5	6.57	50.43	WPSMH	Y	7	M	L	Y	0.88	G	0.14
R GOLD 37	71.2	0.30	42.19	LPS	Y	15	M	M	Y	0.92	G	0.13
R GOLD 37	65.9	-3.86	53.80	MER	Y	8	M	L	Y	0.88	G	0.13
R GOLD 37	65.1	8.07	47.77	MH	Y/T	7	M	L	Y	0.86	G	0.13
R GOLD 37	65.2	11.35	48.27	TUN	T	9	M	L	Y	0.88	G	0.16
R BROWN 38	28	13.99	45.77	CWF	BWN	20	L	M	R	0.79	R/Y	.36/.16
R BROWN 38	33.5	6.62	52.52	WPS	BWN	19	L	M/L	R	0.80	Y	0.23
R BROWN 38	31	12.18	50.25	WPSMH	BWN	18	L	M/L	R/Y	.79/.68	R	0.34
R BROWN 38	38.9	0.53	43.1	LPS	OV	8	M	L	G	0.88	Y	0.17
R BROWN 38	27.7	6.08	46.83	MER	BWN	14	L	L	G	0.84	Y	0.09
R BROWN 38	29.1	15.62	47.27	MH	BWN	16	L	M	R	0.78	Y	0.20
R BROWN 38	29.2	18.37	45.48	TUN	BWN	20	L	L	R	0.78	Y	0.21
R GREEN 39	27.3	-56.52	2.28	CWF	G	13	M	M	G	0.85	B	0.19
R GREEN 39	13.9	-31.77	-34.41	WPS	BG	15	L	M	B/G	.76/.62	B	0.38
R GREEN 39	23.3	-54.17	-10.81	WPSMH	BG	14	L	M	G	0.79	B	0.22
R GREEN 39	4.2	-3.44	-46.42	LPS	BK	12	L	L	B	0.10	B	0.07
R GREEN 39	25.1	-36.88	28.81	MER	G	18	L	M	G	0.93	B	0.13
R GREEN 39	27.9	-61.23	-2.04	MH	BG	12	M	M	G	0.77	B	0.27
R GREEN 39	27.1	-65.76	-14.74	TUN	BG	12	M	H	G	0.75	B	0.26
R BLUE 40	12.8	9.88	-53.66	CWF	B	20	L	H	B	0.99	R	0.06
R BLUE 40	7.2	-4.41	-66.27	WPS	B	20	L	H	B	0.99	-	-
R BLUE 40	11.3	-3.98	-54.89	WPSMH	B	20	L	H	B	0.99	-	-
R BLUE 40	4.2	-0.53	-61.25	LPS	BK	15	L	L	B	1.00	B	0.05
R BLUE 40	7.6	35.72	-56.65	MER	B	18	L	M	B	0.96	R	0.15
R BLUE 40	13.6	-1.42	-50.29	MH	B	20	L	H/M	B	0.98	R	0.09
R BLUE 40	12.7	-13.32	-56.38	TUN	B	20	L	H	B	1.00	-	-
R WHITE 41	78.5	-1.09	1.16	CWF	GY	11	H	-	-	-	-	-
R WHITE 41	78.4	-0.42	0.32	WPS	W	14	H	-	-	-	-	-
R WHITE 41	78.5	-0.85	1.41	WPSMH	W	15	H	-	-	-	-	-
R WHITE 41	78.4	-0.03	1.88	LPS	Y	18	M	M	Y	0.95	G	0.08
R WHITE 41	78.6	-1.06	2.27	MER	W	14	H	-	-	-	-	-
R WHITE 41	78.5	-1.15	1.64	MH	GY/W	10	H	-	-	-	-	-
R WHITE 41	78.4	-1.18	0.36	TUN	W	11	H	-	-	-	-	-
RF ORANGE 42	67.5	62.33	99.80	CWF	O	19	M	H	R	0.61	Y	0.39
RF ORANGE 42	69.5	36.75	95.65	WPS	O	18	M	H	Y	0.62	R	0.38
RF ORANGE 42	68.3	50.04	96.96	WPSMH	O	18	M	H	R	0.57	Y	0.43
RF ORANGE 42	68.3	14.51	5.34	LPS	O	18	M	M	Y	0.69	R	0.32
RF ORANGE 42	63.3	74.34	94.92	MER	O	17	M	H	R	0.59	Y	0.41
RF ORANGE 42	69.9	63.54	101.90	MH	O	20	M	H	R	0.55	Y	0.45
RF ORANGE 42	68.2	56.63	107.42	TUN	O	20	M	H	R	0.57	Y	0.43

Table 3B Continued

RF Y-GREEN 43	85.1	-21.15	107.99	CWF	YG	15	H	H	Y	0.80	G	0.20
RF Y-GREEN 43	85.5	-4.95	97.66	HPS	Y	11	H	M	Y	0.92	G	0.10
RF Y-GREEN 43	88.0	-14.40	106.45	HPSMH	YG	12	H	M	Y	0.85	G	0.16
RF Y-GREEN 43	81.7	0.29	4.55	LPS	Y	19	M	M	Y	0.97	-	-
RF Y-GREEN 43	90.0	-26.60	116.96	MER	YG	13	H	H	Y	0.74	G	0.26
RF Y-GREEN 43	90.4	-19.59	113.01	MH	YG	13	H	H	Y	0.79	G	0.22
RF Y-GREEN 43	84.0	-9.12	84.53	TUN	Y/YG	9	H	M	Y	0.87	G	0.16
F MAGENTA 44	66.1	85.54	12.96	CWF	PK	15	H/M	H	R	0.89	B	0.15
F MAGENTA 44	72.8	53.94	26.96	HPS	PK	14	M	H/M	R	0.87	Y	0.24
F MAGENTA 44	69.7	72.52	19.16	HPSMH	PK	13	M	H	R	0.89	B	0.14
F MAGENTA 44	65.0	34.17	34.55	LPS	O	15	M	M	R	0.69	Y	0.31
F MAGENTA 44	62.1	101.93	-3.78	MER	PK	11	M	H	R	0.89	B	0.14
F MAGENTA 44	68.8	88.56	16.40	MH	PK	9	M	H	R	0.87	B	0.17
F MAGENTA 44	71.4	77.97	31.03	TUN	PK	10	M	H	R	0.85	B/Y	.18/.16
F RED 45	63.1	80.72	40.51	CWF	PK	9	M	H	R	0.88	Y	0.16
F RED 45	71.5	54.53	50.53	HPS	RO/O	7	M	H	R	0.77	Y	0.26
F RED 45	67.8	70.63	45.38	HPSMH	PK	7	M	H/M	R	0.88	Y	0.13
F RED 45	63.8	36.24	31.36	LPS	O	12	M	H	R	0.67	Y	0.33
F RED 45	60.8	96.32	29.59	MER	R	10	M	H	R	0.92	B	0.1
F RED 45	67.1	85.34	43.67	MH	R	11	H/M	H	R	0.88	B	0.16
F RED 45	71.1	78.24	55.40	TUN	R	9	M	H	R	0.86	Y	0.15
R O-RED 46	65.6	81.73	62.27	CWF	O	6	M	H	R	0.79	Y	0.23
R O-RED 46	73.4	54.20	69.99	HPS	O	15	M	H	R	0.66	Y	0.34
R O-RED 46	69.9	71.18	65.88	HPSMH	O	9	M	H	R	0.77	Y	0.24
R O-RED 46	65.5	35.16	42.85	LPS	O	16	M	M	R	0.64	Y	0.36
R O-RED 46	62.8	96.26	50.55	MER	R	9	M	H	R	0.84	Y	0.18
R O-RED 46	69.9	87.67	65.21	MH	R	7	M	H	R	0.77	Y	0.23
R O-RED 46	73.4	79.22	74.12	TUN	O	8	M	H	R	0.75	Y	0.27
F R-ORANGE 47	68.3	81.61	78.75	CWF	O	10	M	H	R	0.67	Y	0.33
F R-ORANGE 47	73.5	51.68	80.64	HPS	O	16	M	H	R	0.61	Y	0.39
F R-ORANGE 47	70.5	68.26	77.72	HPSMH	O	11	M	H	R	0.69	Y	0.31
F R-ORANGE 47	68.0	30.55	41.71	LPS	O	17	M	M	R	0.62	Y	0.38
F R-ORANGE 47	65.1	94.73	68.84	MER	O	8	M	H	R	0.72	Y	0.28
F R-ORANGE 47	70.9	84.66	78.81	MH	O	11	M	H	R	0.68	Y	0.32
F R-ORANGE 47	74.9	77.76	85.13	TUN	O	15	M	H	R	0.64	Y	0.36
F ORANGE 48	76.4	72.12	89.65	CWF	O	18	M	H	R	0.60	Y	0.40
F ORANGE 48	85.9	42.82	97.03	HPS	O	20	M	H	R	0.60	Y	0.40
F ORANGE 48	81.0	59.22	92.48	HPSMH	O	18	M	H	R	0.60	Y	0.40
F ORANGE 48	83.3	16.97	12.40	LPS	O	20	H	M	Y	0.69	R	0.45
F ORANGE 48	77.2	86.99	83.89	MER	O	20	M	H	R	0.58	Y	0.42
F ORANGE 48	85.3	78.02	96.04	MH	O	20	M	H	R	0.55	Y	0.45
F ORANGE 48	80.7	67.61	90.95	TUN	O	19	M	H	R	0.58	Y	0.42
F Y-ORANGE 49	89.0	52.27	107.62	CWF	O	19	M	H	Y	0.66	R	0.34
F Y-ORANGE 49	93.3	24.69	105.16	HPS	O	13	M	H	Y	0.75	R	0.25
F Y-ORANGE 49	92.2	40.18	110.46	HPSMH	O	17	H	H/M	Y	0.71	R	0.29
F Y-ORANGE 49	94.4	4.18	1.05	LPS	Y	19	M	H	Y	0.95	R	0.09
F Y-ORANGE 49	94.7	55.85	114.34	MER	O	19	H	H	Y	0.68	R	0.32
F Y-ORANGE 49	88.7	60.19	105.03	MH	O	17	H	H	Y	0.64	R	0.36
F Y-ORANGE 49	89.3	51.34	109.45	TUN	O	20	H	H	Y	0.70	R	0.30

Table 3B Continued

F G-YELLOW 50	100.0	-26.76	101.80	CWF	YG	14	H	H	Y	0.78	G	0.22
F G-YELLOW 50	101.6	-4.48	87.18	HPS	Y	13	H	H	Y	0.90	G	0.16
F G-YELLOW 50	101.3	-16.95	94.03	HPSMH	YG	13	H	H	Y	0.82	G	0.20
F G-YELLOW 50	98.4	0.44	-15.95	LPS	Y	20	H	H	Y	0.98	R	0.02
F G-YELLOW 50	105.9	-34.35	109.44	MER	YG	14	H	H	Y	0.74	G	0.26
F G-YELLOW 50	106.0	-25.18	100.12	MH	YG	14	H	H	Y	0.79	G	0.24
F G-YELLOW 50	98.3	-9.09	86.48	TUN	Y	10	H	M	Y	0.86	G	0.17
F GREEN 51	69.4	-59.10	60.80	CWF	G	13	M	H	G	0.82	Y	0.23
F GREEN 51	61.8	-27.27	34.77	HPS	G	16	M	M	G	0.82	Y	0.25
F GREEN 51	67.4	-48.34	48.94	HPSMH	G	15	M	M	G	0.86	Y	0.16
F GREEN 51	53.3	-0.53	-0.51	LPS	OV	7	M	L	Y	0.86	G/Y	.19/.21
F GREEN 51	76.1	-45.95	73.52	MER	G	10	M	M	G	0.78	Y	0.24
F GREEN 51	74.9	-60.34	58.82	MH	G	12	M	H	G	0.79	Y	0.24
F GREEN 51	66.6	-60.07	42.38	TUN	G	15	M	H	G	0.84	Y	0.20
F BLUE 52	40.3	-14.06	-55.31	CWF	B	20	M	M	B	0.99	G	0.10
F BLUE 52	31.9	-13.40	-79.60	HPS	B	20	M	M	B	0.99	-	-
F BLUE 52	38.6	-19.28	-69.55	HPSMH	B	20	M	M	B	0.99	R	0.08
F BLUE 52	25.9	-0.52	-38.50	LPS	GY	13	L	L	R	0.66	Y	0.28
F BLUE 52	39.5	13.86	-62.80	MER	B	20	M	M	B	0.99	R	0.08
F BLUE 52	44.5	-20.21	-65.69	MH	B	20	M	M	B	0.99	G	0.05
F BLUE 52	40.6	-37.29	-61.68	TUN	B	20	M	M	B	0.96	G	0.11
F MAGENTA 53	54.6	75.80	-17.62	CWF	MG	9	M	H	R	0.83	B	0.18
F MAGENTA 53	60.3	48.07	-10.78	HPS	PK	12	M	H	R	0.85	B	0.20
F MAGENTA 53	57.8	63.38	-15.12	HPSMH	PK	9	M	H	R	0.81	B	0.23
F MAGENTA 53	51.9	27.63	18.42	LPS	R/O	8	M	M	R	0.79	Y	0.23
F MAGENTA 53	52.4	92.96	-32.70	MER	MG	8	M	H	R	0.79	B	0.21
F MAGENTA 53	59.2	79.98	-18.12	MH	PK	11	M	H	R	0.81	B	0.20
F MAGENTA 53	63.3	72.08	-0.62	TUN	PK	8	M	H	R	0.88	B	0.15
R BLUE 54	18.1	0.69	-49.45	CWF	B	20	L	H/M	B	0.99	-	-
R BLUE 54	9.8	-8.77	-70.65	HPS	B	20	L	H	B	0.99	-	-
R BLUE 54	15.8	-11.13	-50.07	HPSMH	B	20	L	H	B	0.97	G	0.08
R BLUE 54	3.8	-0.36	-20.79	LPS	BK	16	L	L	B	1	B	0.05
R BLUE 54	10.6	27.97	-53.41	MER	B	18	L	M	B	0.94	R	0.13
R BLUE 54	18.2	-8.88	-47.67	MH	B	20	L	H	B	0.98	R	0.07
R BLUE 54	15.0	-20.05	-48.37	TUN	B	18	L	H	B	0.96	G	0.18
R B-GREEN 55	25.7	-36.67	1.79	CWF	G	14	M	M	G	0.87	B	0.18
R B-GREEN 55	16.3	-23.06	-22.60	HPS	BG	12	L	M	G	0.78	B	0.22
R B-GREEN 55	21.7	-33.11	-6.33	HPSMH	BG	13	M	M	G	0.79	B	0.22
R B-GREEN 55	11.8	-0.82	-0.56	LPS	BK	16	L	-	-	-	B	0.04
R B-GREEN 55	27.5	-22.31	13.89	MER	G	18	M/L	M	G	0.89	B	0.14
R B-GREEN 55	25.8	-39.60	-0.96	MH	G/BG	10	M	M	G	0.84	B	0.20
R B-GREEN 55	29.2	-44.98	-8.55	TUN	BG	11	M	M	G	0.82	B	0.20

Table 3B Continued

RF ORANGE 56	66.0	50.78	90.12	CWF	O	19	M	H	R/Y	.57/.68	R/Y	.32/.44
RF ORANGE 56	61.4	27.17	80.29	HPS	O	18	M	M	R	0.54	Y	0.46
RF ORANGE 56	67.5	41.05	90.56	HPSMH	O	20	M	H	Y	0.69	R	0.31
RF ORANGE 56	56.8	12.26	12.21	LPS	O	13	M	L	Y	0.77	R	0.24
RF ORANGE 56	66.6	70.64	95.49	MER	O	20	M	H	Y	0.60	R	0.40
RF ORANGE 56	71.8	55.52	99.39	MH	O	19	M	H	R	0.55	Y	0.45
RF ORANGE 56	62.6	40.10	84.90	TUN	O	20	M	M	Y	0.65	R	0.35
F RED 57	39.4	45.58	23.63	CWF	R	17	M	M	R	0.90	B	0.12
F RED 57	41.4	30.32	25.93	HPS	R	17	L	M	R	0.90	Y	0.14
F RED 57	41.4	39.17	24.34	HPSMH	R	15	M	M	R	0.93	B	0.10
F RED 57	35.7	15.44	12.21	LPS	R	8	M	L	R	0.92	Y	0.10
F RED 57	38.8	49.61	20.32	MER	R	18	M	M	R	0.93	B	0.09
F RED 57	42.5	49.09	25.92	MH	R	19	M	M	R	0.91	B	0.13
F RED 57	47.8	55.66	34.21	TUN	R	17	M	H	R	0.94	Y	0.13
F RED 58	37.8	43.13	17.47	CWF	R	14	M	M	R	0.90	B	0.13
F RED 58	41.4	28.26	18.89	HPS	R	14	L	M	R	0.92	B	0.15
F RED 58	40.0	36.86	19.10	HPSMH	R	13	M	M	R	0.91	B	0.12
F RED 58	35.1	12.49	10.56	LPS	BWN	9	M	M/L	R	0.85	Y	0.17
F RED 58	37.0	45.99	12.27	MER	R	16	L	M	R	0.90	B	0.16
F RED 58	40.9	44.83	18.67	MH	R	13	M	M	R	0.88	B	0.13
F RED 58	46.6	53.91	32.18	TUN	R	20	M	H	R	0.94	B/Y	.09/.12

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☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)*

The present report provides data on the color appearance and physical measurements of 58 safety color samples viewed under each of seven light sources. Ten observers participated in an experiment which determined the accuracy with which different color samples could be identified under sources which varied in spectral composition. The seven light sources included incandescent, cool white fluorescent, clear mercury, metal halide, metal halide-high pressure sodium mix, high pressure sodium, and low pressure sodium. Color samples included ones for safety red, orange, yellow, green, blue, purple (magenta), brown, white, gray, and black of several different types including ordinary, fluorescent, retroreflective, and retroreflective fluorescent. Analysis of the data indicated that the standard ANSI (American National Standards Institute) samples were often not identified accurately under many of the sources studied, with particularly poor performance for the two sodium sources and clear mercury. Specifications are given for a new set of samples that were identified more accurately under all seven sources and which showed a greater gamut of coloration in a uniform color space for all sources. Chromaticity and luminance coordinates for all 58 color samples are presented for both CIE x,y,Y and CIE L*a*b* values. In addition, the psychophysical data are compared with the CIELAB data.

12. KEY WORDS *(Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)*

chromaticity, color, color appearance, energy-efficient lights, high-intensity discharge lights, illumination, light source, safety colors, vision.

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