CPSA 6 (b)(1) Cleared 4/29/96
No Mfrs/Prvtlbrs or Products Identified
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LOG OF MEETING

DIRECTORATE FOR ENGINEERING SCIENCES

SUBJECT: Bicycle Reflector Project Meeting

DATE OF MEETING: March 13, 1996, 1:00 P.M. - 5:00 P.M.

PLACE: Consumer Product Safety Commission, 4330 East West Highway, Bethesda, Maryland

LOG ENTRY SOURCE: Mark Kumagai, ESME MK

DATE OF ENTRY: April 15, 1996

COMMISSION ATTENDEES: see enclosure 1.

NON-COMMISSION ATTENDEES: see enclosure 1.

SUMMARY OF MEETING

CPSC Staff Presentation:

On March 13, 1996 the Consumer Product Safety Commission (CPSC) staff presented an overview of the Bicycle Reflector Project to the bicycle and reflector industry, visibility experts, bicycling interest groups, and other government agencies. The purpose of the meeting was to inform the public of the CPSC Bike Reflector Project and to solicit ideas from interested parties. The CPSC staff presented the project purpose, objectives, approach and a draft test methodology to evaluate the existing requirements for reflectors. Enclosure (2) is a copy of the CPSC staff's presentation.

The CPSC staff reported that over 300 bicyclists die each year in nighttime crashes with motor vehicles. The CPSC analysis showed the risk of death from riding at night is about 7.5 times the risk during the day. In November 1994, the CPSC held a conference on nighttime bicycle riding and in June 1995 the Commission approved the Bicycle Reflector Project.

The CPSC staff plans to evaluate the adequacy of the current reflector requirements (16 CFR part 1512), and investigate passive improvements. The Directorate for Epidemiology and Health Sciences is collecting data from the National Highway Traffic Safety Administration (NHTSA), the Federal Highway Administration (FHWA) and other sources. The Directorate for Engineering Sciences is working with the FHWA to conduct laboratory photometric testing of various bicycle reflectors. Engineering Sciences is also planing a field test to measure driver detection and recognition distances for a variety of reflector systems; some of the systems are to be determined. Enclosure (3) is the draft test methodology.

General Discussion:

Following the CPSC staff's presentation, the meeting was opened for general discussion. The participants discussed using a human cyclist to make the CPSC's field test more realistic. CPSC staff and others were concerned that the safety risk would make this impractical, but a mannequin could be used. Some researchers said that the brightness of a reflector is not the only factor in detection and recognition of a bicyclist. Other important factors include motion, distance cues, color and shape recognition. Testing in different environmental conditions such as the dusk time frame or in fog or rain were discussed. Researchers cautioned the CPSC staff on the complexities and cost to run this type of test. Some suggested that the CPSC investigate conducting static testing using a stationary automobile.

Richard Bloomberg, a researcher, said that the translational motion of the bicycle is an important visual cue when a motorist approaches a bicyclist orthogonally. He recognized the difficulties of simulating this in a field test. Using a stationary bicycle with the pedal reflectors in motion should be a good simulation for a motorist approaching a bicyclist from the rear. His research also showed that the human form is also important for visual recognition of a bicycle. He suggested, based on his experience in conducting a similar study, the CPSC staff carefully develop measures of effectiveness and rationale for selection of the test targets. He also pointed out the difficulties in locating and arranging a test site. He suggested using the U.S Army Reserve Base, Camp Atterbury near Columbus, Indiana to conduct the CPSC field test.

John Forester, a cyclist, suggested that the CPSC staff consider using the data from a study by Ken Cross to determine the accident scenario. He believes that side reflectors are ineffective to an orthogonally approaching motorist because they are not illuminated in time to avoid a collision. Some participants disagreed, because the spread of the headlight beam could illuminate the side reflectors making the bicyclist visible to the diver of an orthogonally approaching vehicle.

Several participants recommended that the CPSC address the nighttime problem through an information and education program. John Schubert, an industry consultant, requested that the CPSC develop a bicycle hang tag to inform the consumer of the danger of nighttime riding. The CPSC staff informed him that a hang tag has been developed. CPSC staff and some participants were aware of increased interest by National Highway Traffic Safety Administration (NHTSA) in the area of pedestrian and bicyclist safety. Alcohol involvement in car and bike incidents was also discussed. Noel Vyrash of the League of American Bicyclists, stressed the importance of understanding the characteristics of the bicyclist population such as commuters or perhaps low income. He and other participants thought that adults who had their driver's license revoked may now be drinking and cycling. Alcohol involvement, either with the motorist or the bicyclist, should be considered in the CPSC's study.

Michael Kershow of the Bicycle Manufacturers of America, requested that the scope of the CPSC project be defined in more detail. He thought that the scope of the project was to evaluate the mechanical and photometric requirements of the existing standard. He said that lights should be used with reflectors while riding at night, but questioned the CPSC's draft plan to including lights as part of a CPSC reflector study. CPSC staff responded that lights were being considered as a data point in the testing and to determine detection and recognition distances for an active source. Kershow also questioned the use of reflective helmets as part of the study. The CPSC staff explained that the reflective helmets are being evaluated as part of the helmet project and would not impact the bicycle reflector requirements. He felt that the CPSC should consider a strong education effort to inform the public of the hazards of nighttime riding.

Presentations:

Thomas Prehn and Seiji Tsuyama, representing Cateye, presented a history of bicycle reflectors. They showed how technology improvements have resulted in smaller and brighter reflectors. They showed European style reflectors and rear lights that also met the CPSC reflector requirement.

Chet Bacon of 3M, presented bicycle reflective products and demonstrated various fluorescent treatments. Products included reflective tires, a plastic reflective tube that is woven around the spokes and fluorescent reflective sheet. He presented a photometric comparison of bicycles with the CPSC reflectors, to reflective tires or wheel circles and various combinations of fluorescent front, rear and side treatments. Enclosure (4) shows the bicycle configurations tested and the test results. He gave the CPSC staff studies shown in Enclosure (5).

Scott Burison of Lazer Loops, presented an invention that used a sheet reflector mounted through a standard spoke reflector so it could be seen from the rear. Seeing cyclists injured in automobile accidents in his work in healthcare inspired him to develop the Lazer Loops. He believes his invention takes advantage of the wheel motion which provides a motorist an identification of a bicycle and indication of its speed. He said that his product has been well received.

Keith Alexander of KTLA products, presented a triangular reflective sheet that mounted to the spokes.

Jeff Williams of Reflectonite, presented reflective bicycle frames and wheel rims. He explained that the frames were treated with an adhesive-backed thin film reflective product that was not visible during the day, but reflective at night.

John Forester presented his views of the hazards of nighttime riding. He believes that a headlamp and a rear reflector must be used for nighttime riding, and front, side and pedal reflectors should be eliminated because these reflectors mislead the bicyclist into believing it is safe to ride at night. Enclosure (6) is a paper he presented and distributed in the meeting.

Ken Uding of Stimsonite, showed how the coefficient of luminous intensity (R_I) of a retroreflector decreases as the observation angle increases. He showed how observation angle increases as the motorist approaches the bicyclist, which results in a decrease in the R_I of the retroreflector. He believes that bicycle reflectors needed to be visible at long, medium and short distances so the motorist can react to avoid a collision.

Randy Swart of the Bicycle Helmet Safety Institute, presented several helmets that were treated with reflective tape. Mr. Swart is requesting that the Commission include retroreflective requirements in the mandatory bicycle helmet standard that is under development. He stated that having an additional reflective point high up on the head will help to identify the profile of a bicyclist. A participant commented that helmets are a fashion issue and the average person will not wear an ugly helmet.

After the presentations the CPSC staff requested that the participants send in written comments and recommendations. The meeting adjourned at 5:00 pm.

Enclosures (6)

cc: OS (2)
ES
File

Non - Commission Attendees:

Keith Alexander	KTLA Products
John Arens	Federal Highway Administration
Keiko Asahzna	Cateye
Chet Bacon	3M
Richard Blomberg	Dunlap and Associates
Scott Burison	Lazer Loops
Bob Burns	Trek
Maureen Cislo	Product Safety Letter
Sam Cristy	Washington Business Information
Ronald Engle	National Highway Traffic Safety Administration
Carol Tan Esse	Federal Highway Administration
John Fegan	U.S. Department of Transportation Office of the Secretary
James Fitzsimone	Huffy Bicycle Co.
John Forester	Cycling Transportation Engineer
James Green	Resource Engineering
Joe Kagayama	Cateye
Michael Kershow	Bicycle Manufacturers Association
Wayne Kurse	Murray Inc.
D. McDonald	Reflexite
Barbara McMillen	Federal Highway Administration
Thomas Prehn	International Cycle Works
James Rafac	Roadmaster
Mike Rood	Sate-Lite MFG. CO.
Thomas Schnell	Ohio University
John Schubert	Limeport Marketing Group
Randy Swart	Bicycle Helmet Safety Institute
Donald Tighe	League of American Bicyclist
Seiji Tsuyma	Cateye
Dan Turner	Federal Highway Administration
Ken Uding	Stimsonite Corp.
Chris Welch	3M
Noel Weyrich	League of American Bicyclists
J. Whalen	Bureau of National Affairs
Jeff Williams	Reflectonite

Commission Attendees:

Suzanne Cassidy	Directorate for Epidemiology and Health Sciences
Pary Davis	Directorate for Engineering Sciences
Robert Franklin	Directorate for Economics
Scott Heh	Directorate for Engineering Sciences
Sandra Inkster	Directorate for Epidemiology and Health Sciences
Mark Kumagai	Directorate for Engineering Sciences
John Murphy	Directorate for Engineering Sciences
Robert Ochsman	Directorate for Engineering Sciences
Gregory Rodgers	Directorate for Economics
Scott Snyder	Directorate for Engineering Sciences
Andrew Stadnik	Directorate for Engineering Sciences
George Sushinsky	Directorate for Laboratory Sciences
Deborah Tinsworth	Directorate for Epidemiology and Health Sciences
Celestine Trainor	Directorate for Engineering Sciences

Consumer Product Safety Commission

Bicycle Reflector Project

March 13, 1996

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Bicycle Reflector Project

Agenda

- Purpose
- Background, Current Issues, Current Reflector Requirements
- Project Objectives
- CPSC Approach
- Project Schedule and Milestones
- Human Factors Field Test Methodology

Bicycle Reflector Project

Purpose

- Present CPSC Bicycle Reflector Project plans and objectives.
- Discuss CPSC project approach.
- Discuss test and evaluation methodology.
- Solicit input from industry and visibility experts.

Bicycle Reflector Project

Background

- 1974 - Bicycle Requirements 16 CFR Part 1512.
- 1978 - Amendment to allow reflective rims.
- 1994 - CPSC report “Bicycle Use and Hazard Patterns in the United States” published.
- November 1994 - Chairman’s Conference on Nighttime Bicycle Riding held at CPSC.
- June 1995 - Commission approves Bicycle Reflector Project.

Bicycle Reflector Project

Current Issues

- About 300 bicyclists die each year in nighttime crashes with motor vehicles.
- Based on NHSTA's 1994 Fatal Accident Reporting System (FARS), about 800 bicyclist died in crashes with motor vehicles.
- Level of darkness: 18% dark conditions, 16% dark but lighted conditions, 5% dawn or dusk.
- CPSC analysis showed risk of death from riding after dark is about 7.5 times the risk during daylight.

Bicycle Reflector Project

Current Reflector Requirements

- Position and color

Position	Color
rear	red only
front	clear only
pedal	clear or amber
side (spoke, tire, rim)	no specification

- Unobstructed view ± 10 degrees vertical and ± 50 degrees horizontal
- Minimum photometric requirements at specified observation and entrance angles

Bicycle Reflector Project

Project Objective

- Evaluate the adequacy of current reflector requirements.
- Investigate possible passive improvements to increase nighttime conspicuity.
- Report results with recommendations for Commission decision.

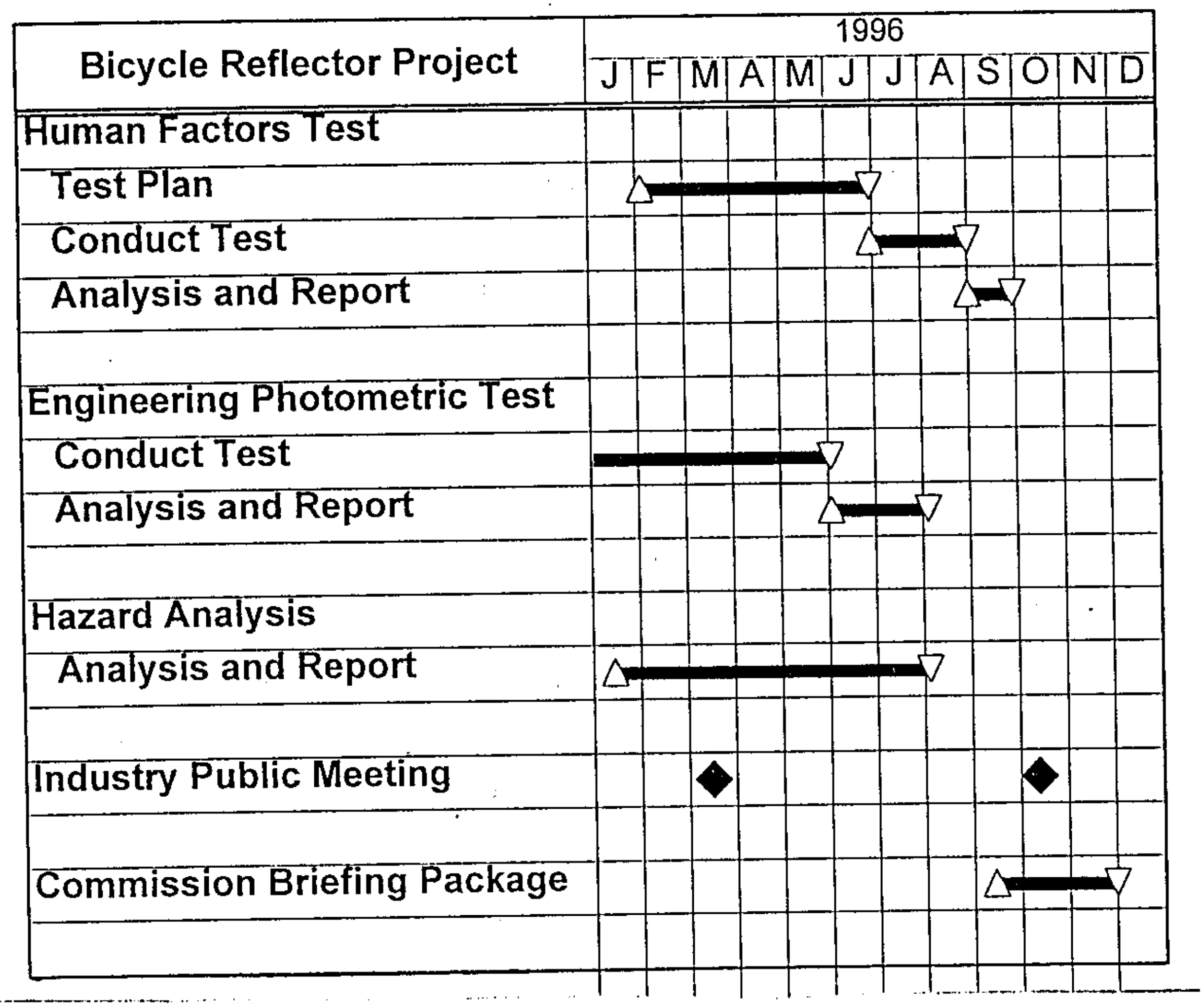
Bicycle Reflector Project

CPSC Approach

- Evaluate incident data to determine general hazard scenarios.
- Conduct laboratory photometric testing to compare reflector systems.
- Conduct controlled field testing of driver detection and recognition of reflector systems.
- Compare test results and data to develop appropriate recommendations.

Bicycle Reflector Project

1996 Bicycle Reflector Project Schedule and Milestones



Bicycle Reflector Project

Human Factors Test

- Objective: Evaluate motorist detection and recognition of targets
- Subjects: Approximately 40, equal male and female, age 25-44
- Test Field: Neighborhood streets with dark roadway, lighted roadway, other background noise, and intersections
  - Key targets will be rotated
  - Decoy targets not rotated

Bicycle Reflector Project

Human Factors Test, cont.

- Targets: 6 motorized bicycles
  - Currently available reflectors (baseline)
  - Baseline + head & tail light
  - Baseline + helmet with reflective tape
  - Baseline + amber rear reflector
  - Two others - TBD (discuss today)

Bicycle Reflector Project

Human Factors Test, cont.

- Stationary Decoy Targets:
  - Traffic cone with reflective tape
  - Detour sign with reflective markings
  - Parked automobile
  - Construction strobe light
  - Other ideas?

Bicycle Reflector Project

Human Factors Test, cont.

- Equipment: Standard automobile, low beam halogen lights, electronic monitoring devices - subject activated, continuous video/audio recording in vehicle

- Test subjects will be only told study is to monitor driver reaction to roadway objects

DRAFT METHODOLOGY FOR CPSC BICYCLE REFLECTOR STUDY

Prepared by C. Trainor, Division of Human Factors, Engineering Sciences 301-504-0468 ext. 1284

Objective. Evaluate motorists' detection and recognition of various bicycle reflector systems.

Subjects. There will be approximately 40 subjects; the actual number is dependent on the final experimental design. The number of males and females will be almost equal. Subjects' ages will range from 25 to 44 years. They will be screened for visual acuity, color blindness, night vision and driving record. Subjects who are color blind, night blind, or have poor driving records will be screened out. There will be an evenly distributed number of subjects within two ten-year age spans (e.g., 25-34 yrs, & 35-44 yrs).

Test Field. The study will be conducted in a field environment closely resembling a real neighborhood. The site will have parts with background visual noise, such as houses with lights, and street lights, and other parts completely dark. The test field will consist of straight-aways and intersections. The testing will be conducted during dusk and dark time periods over consecutive days. Tests will be conducted only in clear, dry weather.

Key targets will be placed in various locations along the route and then will be rotated according to a statistically appropriate design. All subject will see all targets, however, the order of key targets will be changed after a specified number of subjects. Decoy targets will not be moved during the study.

Targets. The study will investigate six targets. The baseline target will be a bicycle with currently available reflectors. The second target will be a bicycle with head and tail lights. Since all 50 states require bicyclist riding at night to use head and tail lights this information can be potentially helpful for reinforcing this law. The third target will be a baseline bicycle with a mannequin wearing a bicycle helmet with reflective markings. The CPSC is currently developing a mandatory bicycle helmet standard and mandating reflectivity on helmets is one part of the regulation being considered. The fourth target will be a bicycle with an amber rear reflector instead of the presently required red reflector. Studies indicate that the brightness of the amber reflector makes the bicyclist more noticeable and therefore is more appropriate than the red reflector. The fifth and sixth targets are yet to be determined based on discussions with industry.

The bicycle targets will be motorized to alleviate the need for humans to be riding the bicycles.

ENCL(3)

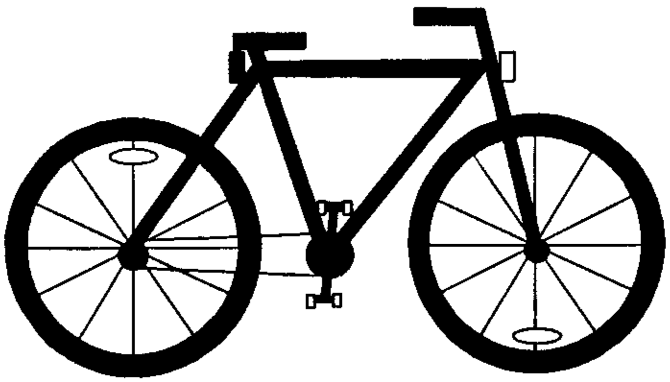
There will be a variety of stationary decoy targets. One target will be traffic cones with reflective marking. Another target will be a detour traffic sign on a construction horse. A third decoy will be a parked car. A fourth decoy will be a construction strobe light. Another decoy will be red reflectors on sticks to indicate the end of driveways.

Equipment. The test subjects will drive a standard motor vehicle with halogen headlights on the low beam setting. They will be instructed to maintain a speed of 25 mph. The vehicle will be equipped with a "Nightstar" recording device to record the distance traveled by the car and the driver's responses. The steering wheel will be equipped with a button for the driver to push when he/she detects an object and when he/she recognizes the object. An experimenter will ride with the subject to monitor the drivers' responses for accuracy. The experimenter will know the correct identify of the targets. If a subject incorrectly identifies a target in either the detection or recognition stage, the experimenter will immediately say "no". The subject will have been instructed to continue to try to identify the target and to push the button again. The experimenter will say "yes" when the target is identified correctly. The vehicle will also be equipped with a video camera to record each test trial.

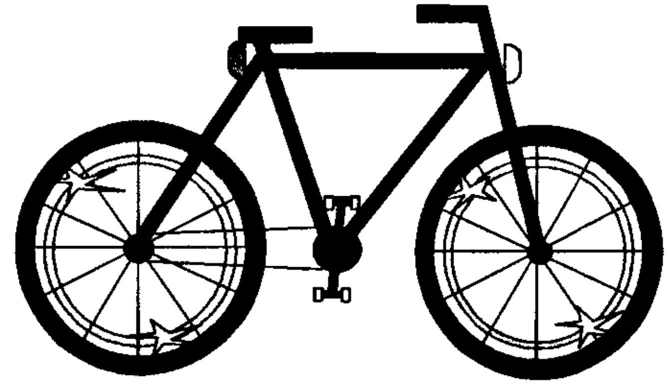
Instructions. Subjects will be told that the study is intended to monitor their reactions to objects which may or may not encroach their driving path. They will be instructed to talk about what they see as they are driving. They will be instructed to push the button on the steering wheel when they detect something that may appear to be in the roadway ahead or that they believe may eventually enter the roadway (i.e., cross their path). They will then be instructed to push the button again, when they believe they have identified the object. Subjects will be instructed that if their response is incorrect the experimenter riding with them will simply state "no" and they are to continue talking about what they see until they identify it correctly. When identified correctly the experimenter will say "yes".

ENCL (3)

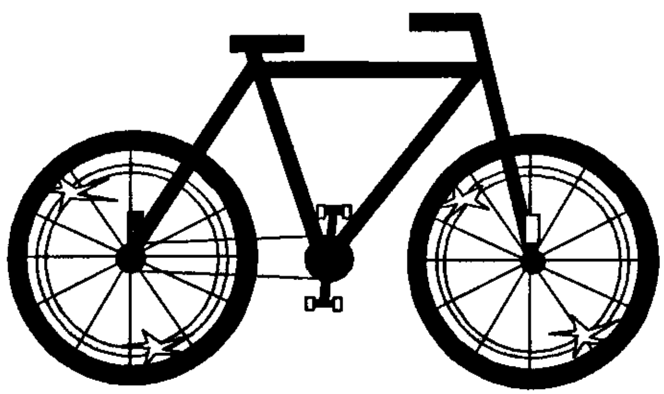
BICYCLE REFLECTORIZATION



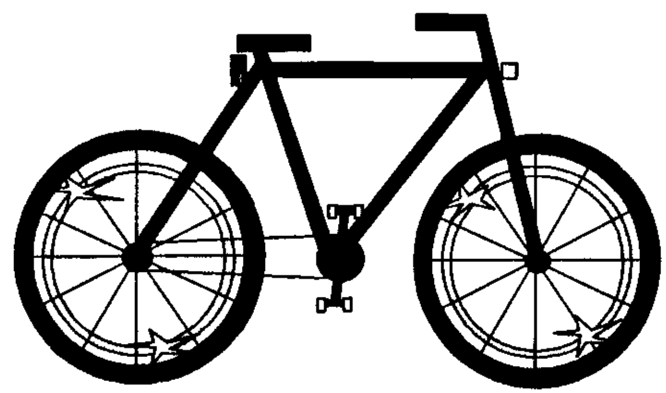
CPSC REFLECTORS, NONPREFERRED
1 (F,R,S,P)



WHEEL CIRCLES, FLUOR ARCS
2 (WC,FA,P)



WHEEL CIRCLES, FLUOR FRAME
3 (WC,FF,P)



WHEEL CIRCLES, FLUOR RECT.
4 (WC,FR,P)

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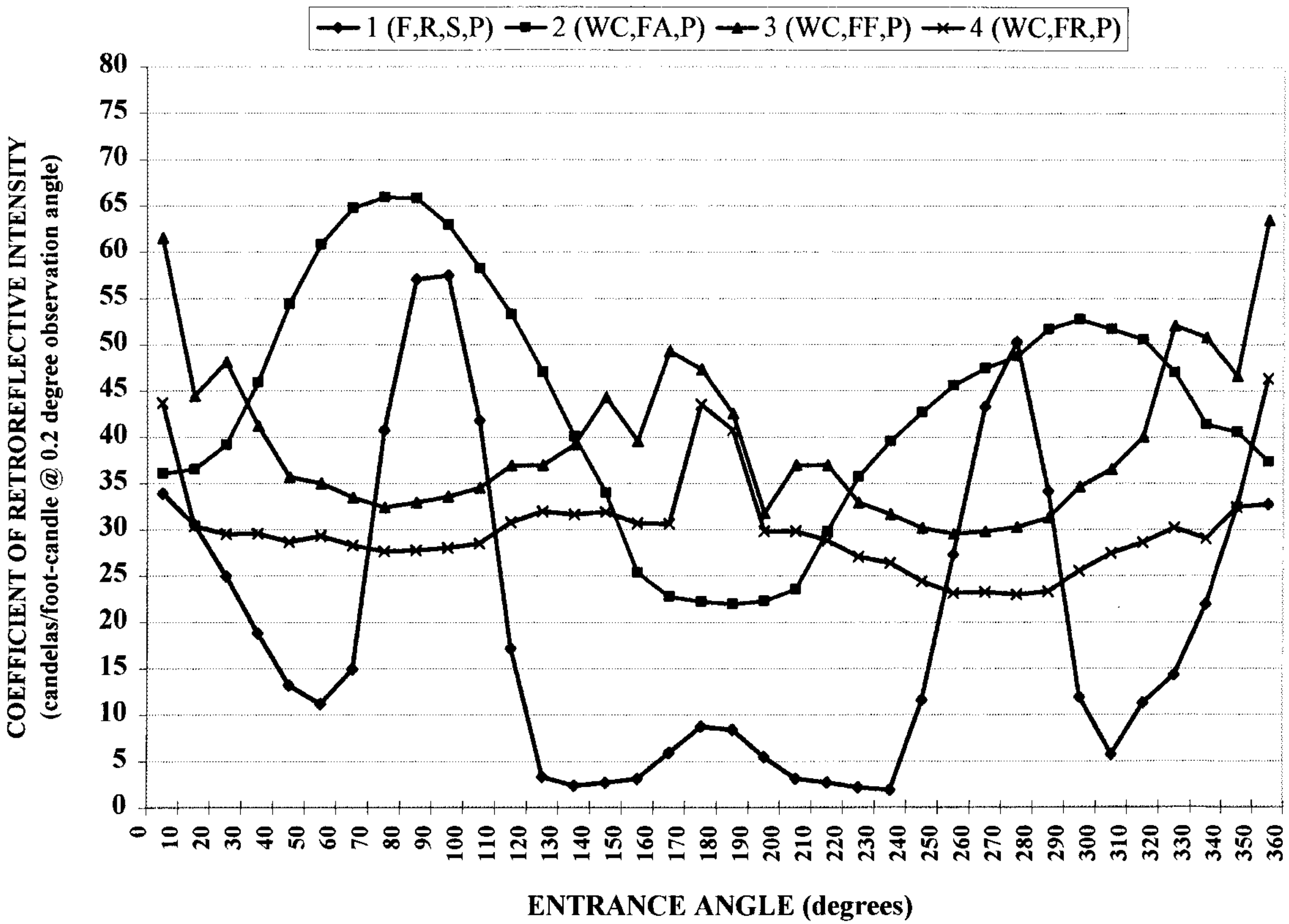
ATTACHMENT

COEFFICIENT OF RETROREFLECTIVE INTENSITY vs ENTRANCE ANGLE on BICYCLES @ 0.2 OBS ANGLE



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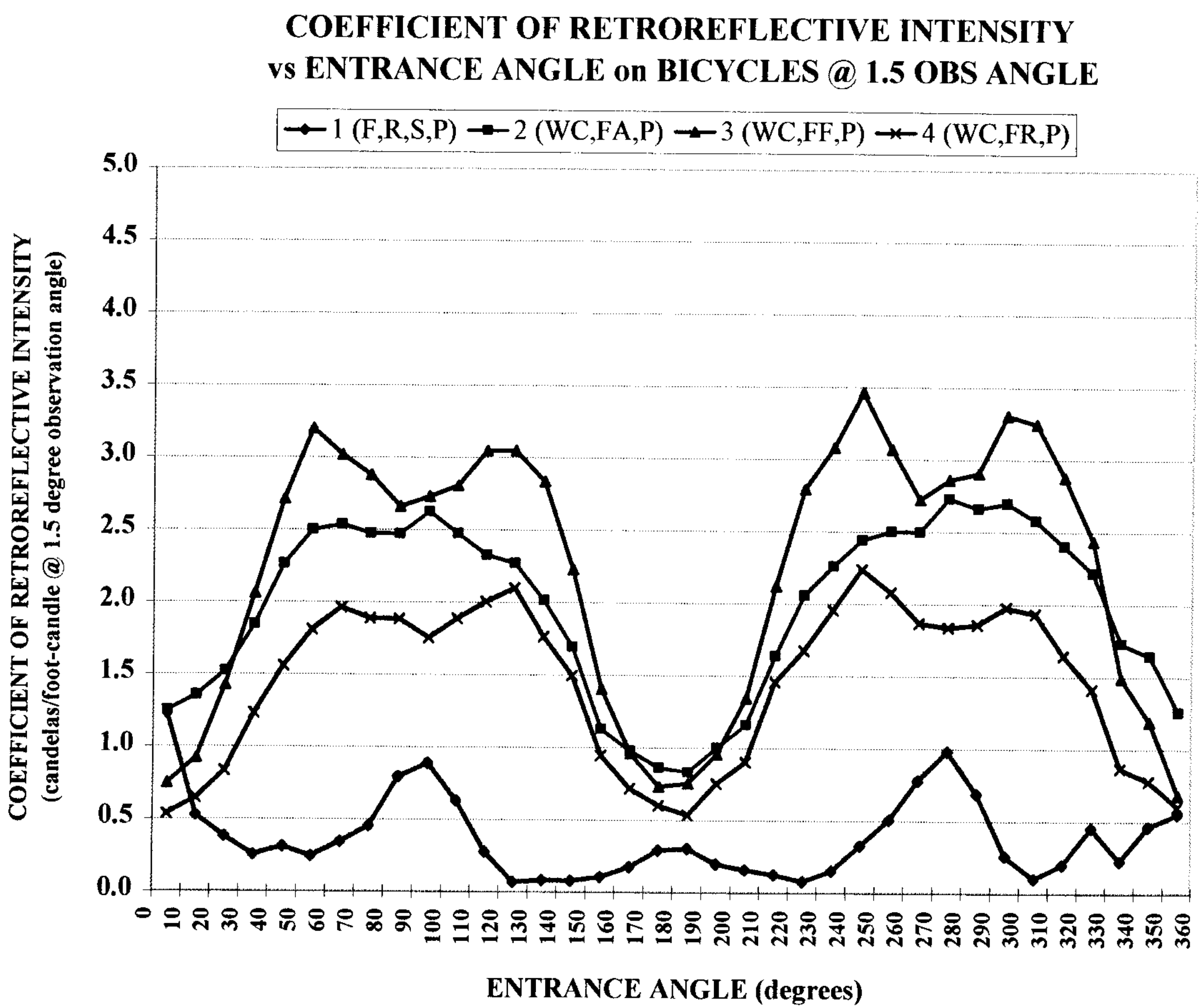
ATTACHMENT



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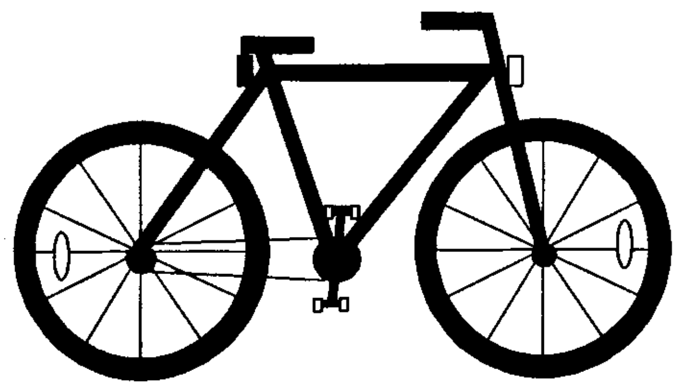
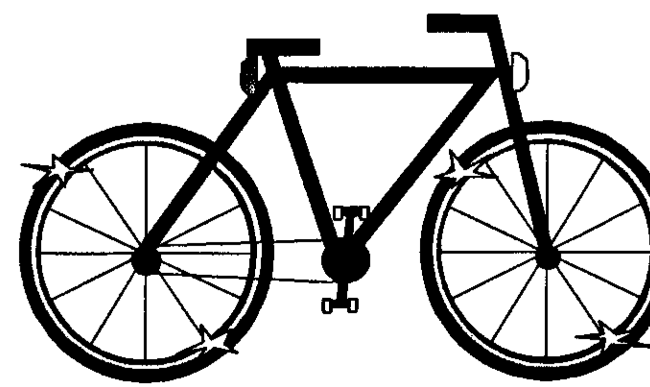
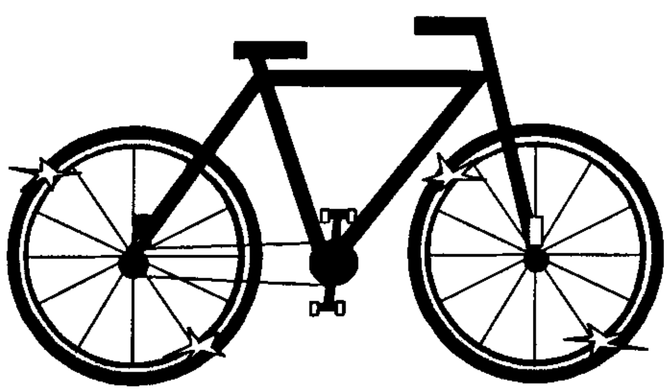
BICYCLE REFLECTORIZATION



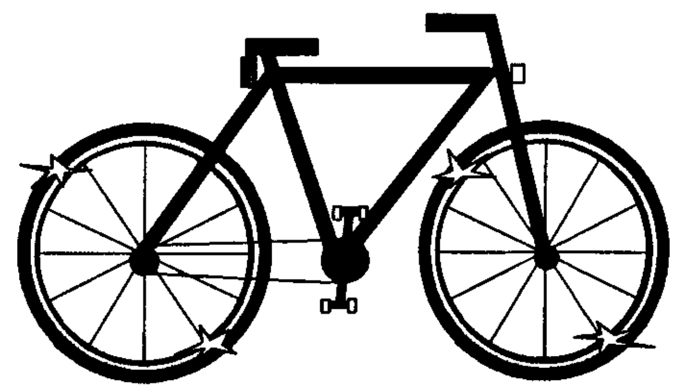
CPSC REFLECTORS, PREFERRED
5 (F,R,S,P)



TIRE CIRCLES, FLUOR ARCS
6 (TC,FA,P)



TIRE CIRCLES, FLUOR FRAME
7 (TC,FF,P)

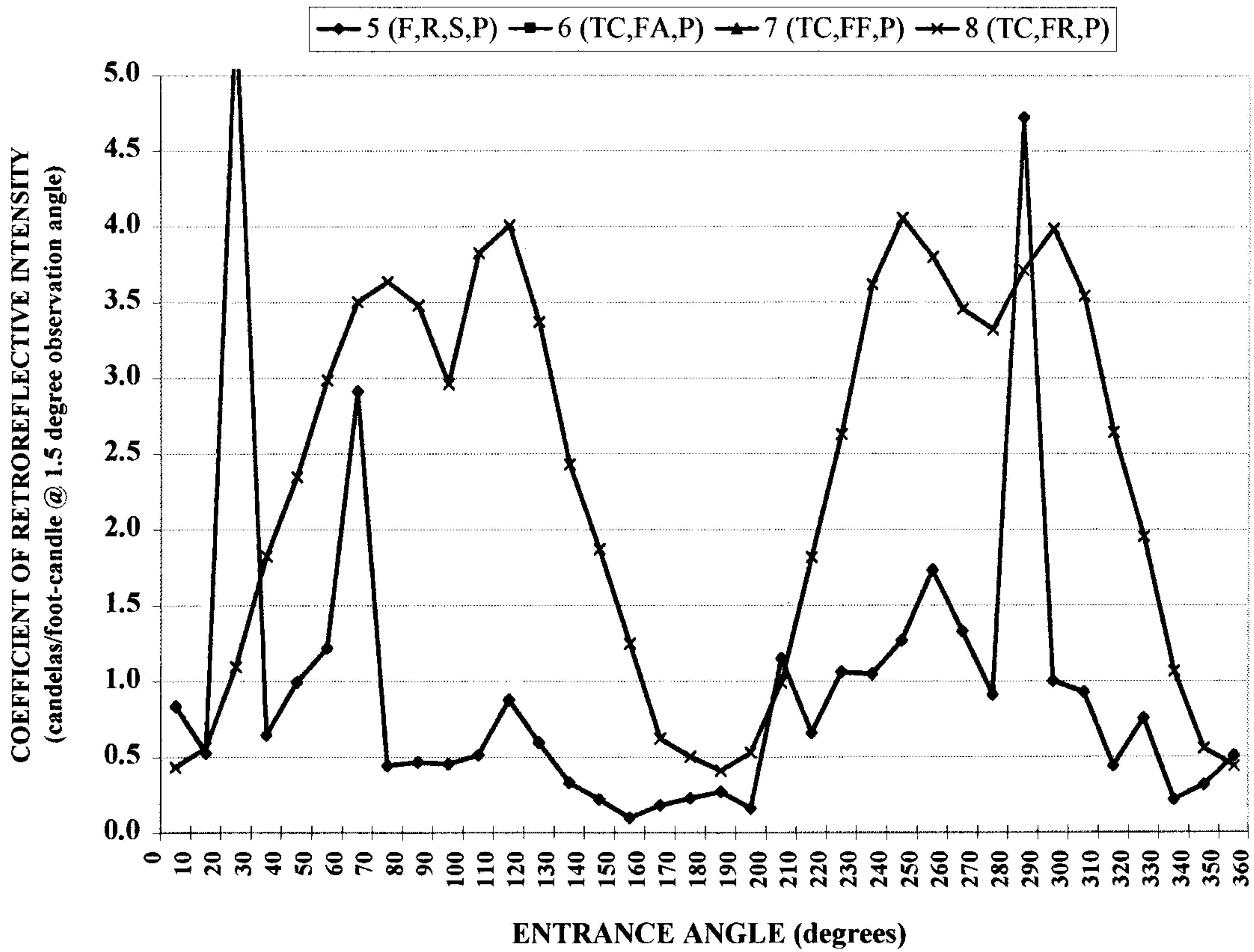


TIRE CIRCLES, FLUOR RECT.
8 (TC,FR,P)

ENCL(4) 4/6

ATTACHMENT

COEFFICIENT OF RETROREFLECTIVE INTENSITY vs ENTRANCE ANGLE on BICYCLES @ 1.5 OBS ANGLE



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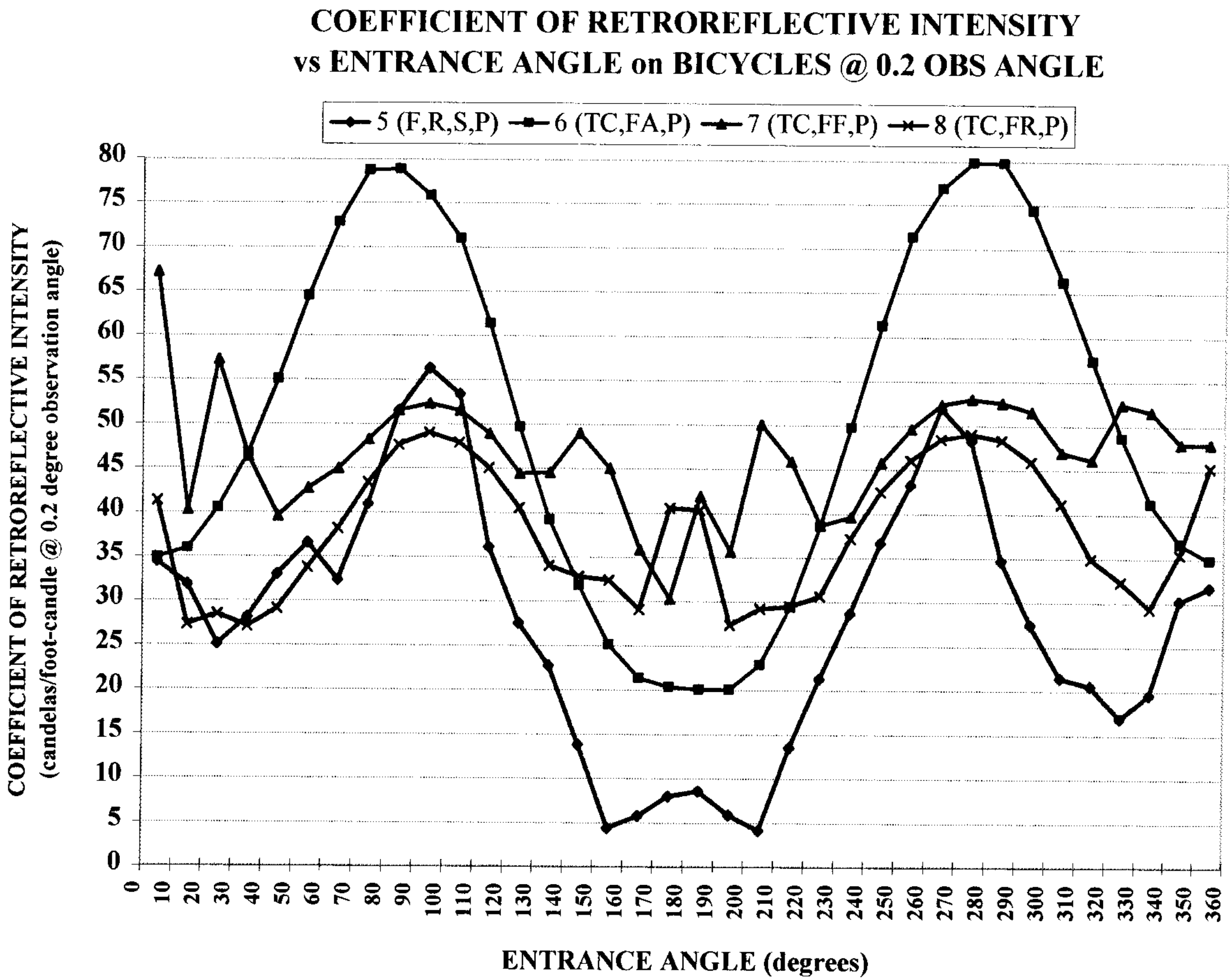

ENCL(4) 6/6

List of Documents from 3M:

1. Proposal for Standard U.S. Headlamp Beam Pattern for Evaluation of Retroreflection, Szczech T.J., Chrysler S.T., Transportation Research Record 1456, National Academy Press, Washington, D.C., 1994.

2. Conspicuity in Terms of Peripheral Visual Detection and Recognition of Fluorescent Color Targets Versus Nonfluorescent Color Targets Against Different Backgrounds in Daytime, Zwahlen H.T., Vel D.V., Transportation Research Record 1456, National Academy Press, Washington, D.C.

3. Conspicuity of Suprathreshold Reflective Targets in a Driver's Peripheral Visual Field at Night, Zwahlen H.T. Transportation Research Record 1213, National Academy Press, Washington, D.C.

4. Motorcycle Reflectorization for Nighttime Conspicuity, Burg A., Beers J., University of California, Los Angeles, UCLA-ENG-76111, November 1976.

5. Bicycle Wheel Reflectorization as an aid to detection and Recognition, Burg A., Hulbert S.F.,

6. Prevention of Two-Wheeled Vehicle Accidents in the Darkness, International Center for Crime and Road Accident Prevention (IZVV), March 1977.

7. Visible Motor-cycles and Mopeds, Stoovelaar F., Groot R.E., Report of a study conducted under auspices of the Royal Dutch Touring Club ANWB.

8. A Visible Bicycle, Stoovelaar F., Groot R.E.,Report of a study conducted under auspices of the Royal Dutch Touring Club ANWB, January 1976.

9. Documents on the problem of two-wheelers and the visual arrangements for road traffic. Prepared by Dr. G.R. de Regt, Royal Dutch Touring Club (ANWB)

10. Evaluation of the Effects on Traffic Safety of the Introduction of side Reflection on Bicycles (partial translation), Blokpoel A., Foundation for Scientific Research on Traffic Safety, Leidschendam, 1990.

11. Nonmotor Travel in the 1990 Nationwide Personal Transportation Survey, Antonakos C. L. Transportation Reserach Record 1502, National Academy Press, Washington, D.C.

12. Bicycle-Motor Vehicle Crash Types: The Early 1990s, Hunter W.W., Pein W.E., Stutts J.C., Transportation Research Record 1502 National Academy Press, Washington, D.C.

13. 1994 Traffic Crashes, Injuries, and Fatalities - Preliminary Report, DOT HS 808222, March 1995, available through National Technical Information Service, Springfield, Va. 22161

14. International Standard (ISO) 6742/2 -1985 (E), Cycles - Lighting and retro-reflective devices - Photometeric and physical requirements - part 2: Retro-reflective devices.

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Cycling Transportation Engineer
Consulting Engineer, Expert Witness & Educator in
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Thursday, March 7, 1996

Bicycle Nighttime Safety Equipment Requirements of the CPSC March, 1996 Meeting

1 Description of the Problem

The Consumer Product Safety Commission has become concerned that the nighttime accident rate for bicyclists greatly exceeds the daytime accident rate. The CPSC staff has been instructed to consider what changes might be made in the standard for bicycles that would reduce these nighttime accidents. As a result of these instructions, the CPSC is holding a meeting in Washington on 13 March, 1996, to consider what should be done.

2 The Permitted Scope of the Consumer Product Safety Commission

The Consumer Product Safety Commission has the authority to set requirements (in the form of standards) for consumer products that apply up to the time of sale to the consumer, but not thereafter. The CPSC has no authority to set standards for the way the products are used, although the CPSC may require the manufacturers of consumer products to provide instructions for the safe use of the products that they make. The limits of the CPSC's authority are set by the Constitution, and its authority exists only because the Constitution allows the federal government to regulate interstate commerce.

Any requirements set by the CPSC preempt all requirements set by local authorities (states, cities, counties, etc.) that pertain to the same risks, at least up to the time of sale to the final consumer. That is, no local authority can require, as a condition of sale, any additional or different equipment for nighttime safety than the CPSC requires.

The CPSC does not have the authority to distinguish between different uses of the same product. If different uses require different products, then the CPSC has the authority to set different requirements for the different products based on the way that each product will be used. However, where one product, or one class of products that are indistinguishable from each other, has several uses, the CPSC has no authority to set different requirements depending on the type of use that the final consumer may choose to make of the item that he or she purchases. Furthermore, the final consumer may well not be the initial purchaser and may well have different purposes in mind.

The CPSC has stated, and its position has been upheld in court, that it cannot distinguish bicycles that will be used by adults from those that will be used by children. Equally, it cannot distinguish those that will be used for recreation from those that will be used as vehicles for transportation, nor those that will be used at night from those that will not be used at night. The inability to distinguish between these uses is not just a legal limitation that might be changed; there is no clear-cut physical way to make such distinctions.

Therefore, any requirements that the CPSC may set must be applied to all bicycles up to the time of sale. The problem is to devise a system that can be implemented within these limits that will significantly reduce nighttime accidents to cyclists more than does the present system. To do

ENCL(6)

that, we need to consider the accidents that now occur and the engineering requirements for reducing their frequency, to see which ones might be susceptible to an improved system that the CPSC can properly require.

3 Classes of Accidents to Cyclists Caused By Darkness

Three types of accidents to cyclists are caused by darkness:

1: Cyclist does not see where he is going and runs off the road, rides over a road surface defect, or collides with a fixed object or pedestrian. In most cases, the cyclist is not using a headlamp and the accident may be attributed to that failure, although in a few cases the cyclist was using a headlamp but still did not see the hazard.

2: Cyclist collides with another cyclist. Generally one or both of the cyclists are without headlamps and failure to use a headlamp is the cause of the accident.

3: Cyclist is involved in a collision with a motor vehicle.

Types 1 and 2 clearly require the use of a headlamp, and reflectors of any quality would not make a difference. Type 3, cyclist involved in a collision with a motor vehicle, is the only type that might be ameliorated by improving the reflector system, because it is the only type in which the object collided with possesses headlamps that might illuminate a reflector at the time required to prevent a collision. We need to investigate the types and frequencies of car-bike collisions to see which ones would be reduced by the use of headlamps and which ones would be reduced by the use of reflectors.

3.1 Car-bike Collisions Caused By Darkness

The only study that provides data on car-bike collisions probably caused by darkness is Cross and Fisher of 1977,[1] whose data are analyzed for this cause in Forester's *Bicycle Transportation*.[2] Forester concludes that 79% of the car-bike collisions probably caused by darkness are of types for which a headlamp is the only satisfactory preventive equipment. In these accidents the car approaches the bicycle from ahead, either from directly ahead on the same street or from diagonally ahead on an intersecting street, generally at right angles to the cyclist's street. Of the accidents of these types that occurred during darkness, Cross ascribes 69% to the absence of a bicycle headlamp.

In 21% of car-bike collisions that are probably caused by darkness, the motor vehicle approaches the bicycle from the rear on the same street. The Cross statistics show no cases in which the motor vehicle approached the bicycle diagonally from the rear, as might occur at a Y intersection.

4 Physical Characteristics of Lights and Reflectors

4.1 Light

Light radiates in straight lines practically instantaneously. It is generated by luminous sources such as the sun and lamps, and is partially reflected and partially absorbed when it falls on most surfaces.

Light varies in quantity, which our eye interprets as brightness, and in wavelength, which our eye interprets as color. What we see as white light from the sun or the slightly yellow light that we see from most incandescent lamps is actually a mixture of all colors from red to violet.

The brightness of a light source is measured in candlepower, originally the brightness of a specified candle. The brightness falls off with the square of the distance, and the intensity of light falling on a surface (including the surface of the eye) is measured in foot-candles, originally the amount of light delivered by the specified candle when observed at a distance of one foot.

4.2 Vehicle Headlamps

Bicycle head lamps send their light out in a pattern that is determined by their mirrors and lenses. The pattern generally consists of a narrow beam of bright light and a wide arc of dimmer light. The narrow, bright beam is used by the cyclist to see where he is going. This beam has to be bright because its light must be reflected from surfaces that typically have low and similar reflectivities. The wide arc of dimmer light is used to show other people the presence of the cyclist. Although this light is dimmer than the beam, it can be seen from a far greater distance than the cyclist can see ahead, and typically over an arc of at least 70 degrees on each side of the center line.

Headlamps for motor vehicles have the same general pattern of bright beam and dimmer arc as bicycle headlamps, but because of their much greater brightness special arrangements are made to limit the top edge of the beam, making it flat-topped, so it will not glare into the eyes of other drivers. Furthermore, each car is equipped with lamps giving two sets of beams. One beam is directed straight ahead and level, for use in rural areas where no other driver is in sight, the other beam dimmer and directed downward and to the right, for use in cities and where other drivers are in sight.

4.3 Reflectors

The reflectors used are technically called retroreflectors because they reflect light falling on them back towards its source. That is, they not only do not generate their own light, but unlike most surfaces they also do not reflect light in a diffuse manner. Each beam of light that falls on a retroreflector is reflected back towards its source.

For reasons of optical science, a retroreflector can operate only over an arc of no more than 40 degrees, 20 degrees on each side of its center line. Beyond that arc, it totally extinguishes.

The performance of a retroreflector is measured in terms of the ratio of its apparent brightness to the intensity of the light falling on it from the same direction. That is, in candlepower per foot-candle. The brightness, in turn, depends on the efficiency of the reflector and its size. A large reflector will appear brighter than a small one because it intercepts more light from the energizing lamp. As is obvious, the brightness of a retroreflector depends directly on the intensity of the light from the motorist's headlamp beams. The brightness of a reflector falls off markedly as the reflector moves away from the center of the headlamp beams of the motor vehicle, merely because the intensity of the light from the headlamps falls off.

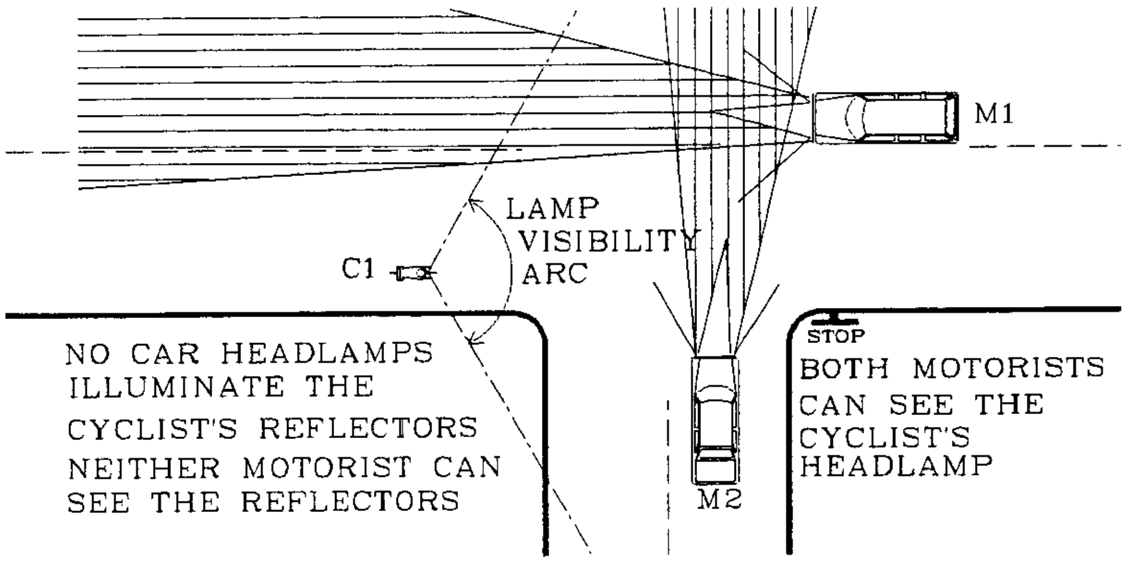
The retroreflectors that are used in highway situations have optical imperfections, both the unavoidable and the designed-in ones. Instead of reflecting the light directly back to its source, they reflect the light in a cone directed around the source and, in some cases, directed slightly above the source. Thus, the reflected light hits the eyes of the driver of a vehicle when his headlamp beams shine on the reflector. The narrower the cone of reflected light, the brighter the reflected beam and the greater the distance at which the reflector can be seen. However, as the driver approaches the reflector, his eyes can get above the reflected beam and, to his vision, the reflector dims and finally extinguishes. Therefore, the design of a reflector is a compromise between brightness at a great distance and brightness when close up. The appropriate design makes the reflector brightest when viewed at the distance at which a collision can be avoided.

5 The CPSC All-Reflector System

The present CPSC system uses 10 reflectors. The 6 main reflectors are placed so that one faces forward, one faces backward, and two face to each side, one on each side of each wheel. The other four reflectors are supposedly placed on the front and back sides of the pedals, but many pedals made today are shaped so they cannot support such reflectors. Each of the main reflectors is a wide-angle reflector. It is made up of three panels set at different angles. Since each panel can reflect over about a 40-degree arc, the single reflector that is made up of the three panels can reflect over about a 100-degree arc. The reflectors are mounted on the bicycle so that each covers a 90-degree arc; forwards, right side, backwards, left side. The amount that each reflector exceeds 90 degrees allows for the inevitable misalignment of the reflectors. The idea behind this system is that whatever the direction from which a car's headlamps may shine on the bicycle, at least one reflector will be positioned to reflect light back to the driver of that vehicle. In that way, so the concept goes, the bicycle is protected against collisions from all angles.

6 The State-Required Headlamp and Rear Reflector System

While the states cannot impose any other requirements for nighttime protective equipment at the time of sale, they universally require different equipment to be used when any bicycle is operated at night. The essentials of the requirements of all states are a headlamp and a rear reflector, although many states also now require the other reflectors specified by the CPSC. The states require headlamps for the valid and sufficient reason that headlamps are absolutely necessary to avoid nighttime car-bike, bike-bike, and bike-pedestrian collisions. No responsible person believes that the all-reflector system can work. For those who do not understand, Figure 1 shows two of the typical car-bike collision situations that have much higher frequencies at night, in both of which



the all-reflector system will not work. Situations similar to these cause 79% of the car-bike collisions that are probably caused by darkness. The inability of the motorist to see the bicycle's reflectors is particularly acute in cities, where most nighttime cycling occurs. This is because motorists in cities use their low beams that are directed low and to the right to keep them out of the eyes of motorists coming from the opposite direction.

The other item required by the states is a rear reflector and, in some states, an additional rear lamp. The rear reflector works because the motorist is coming from directly behind, or almost directly behind, the bicycle. The motor vehicle's headlamp beams shine on the bicycle for a long time before the motorist reaches the bicycle, giving ample time to avoid the collision. On a sharply-curving road the motorist's headlamp beams do not shine upon the cyclist until the motorist is considerably closer, but on such sharply-curving roads the motorist must travel much slower than normal, so there is still time to avoid the collision. The rear reflector does not have to be a wide-angle reflector because the motorist cannot be more than 20 degrees away from the bicycle's center line at any reasonable speed, and in any case his headlamp beams don't reach that far to the side so there is insufficient headlamp light beyond that angle to energize the reflector.

7 The Headlamp Quandary

The engineering conclusion about appropriate nighttime protective equipment is that cyclists must use a headlamp and some form of rear device, which may be a reflector alone or a reflector plus a rear lamp. That is scientifically respectable and it is also what the states require. However, the CPSC cannot reasonably place such a requirement into its standard. I explain why.

Few of the bicycles purchased in the U.S.A. will be used for transportation, even fewer will be used at night, and even fewer will be used regularly at night. With such a small proportion that will be used at night, and therefore a small number of nighttime accidents that might be prevented, if all bicycles were fitted with headlamps the cost per accident prevented would be very high. There is also considerable doubt that fitting every bicycle with a headlamp at time of sale would actually prevent many of the nighttime accidents. This is because headlamps (or rear lamps also) that have been on the bicycle since the time of sale but have not been used for a long time will probably not work when they are needed.

The cost per accident prevented falls dramatically when only those bicycles used at night are equipped with headlamps and rear reflectors.

The proper policy must produce two different effects of equal importance. It must get those bicycles used at night equipped with headlamp and rear reflector. It must also prevent those bicycles not so equipped from being used at night.

We know what needs to be done, but we also recognize that the CPSC can't do it alone.

The question then becomes: how to devise a plan that accomplishes these two effects as best as possible within the scopes of governmental authority and in the context of our society?

8 Solutions to the Headlamp Quandary

8.1 The Old Solution Has Grave Defects

The old solution was the all-reflector system. This was devised by the Bicycle Manufacturers Association, which then persuaded the CPSC to adopt it into the CPSC's regulation. The BMA had two motives for getting this system into national law. The first motive was to get uniform requirements for nighttime protective equipment at time of sale in all states. Before this, each state had its own requirements and many were different. The industry had to supply different kits of items depending on which state each bicycle was shipped to, and this presented a real problem. The second motive was to head off any requirement for supplying headlamps on all bicycles. Besides the wider cost/benefit considerations discussed above, the BMA had to consider that the cost of good lighting equipment would double the cost of the typical bicycle that its members sold, and that after years of non-use the equipment was likely to be defective at the time when it was required. Once the all-reflector system and the companion law by which CPSC requirements preempted local laws were in place, the BMA then tried to get the states' headlamp requirement repealed (arguing that case before the Committee for Uniform Traffic Laws and Ordinances), but the states refused to allow dangerous cycling at night without a headlamp.

The national uniformity argument could have been fulfilled by a less comprehensive system than the all-reflector system. However, the anti-headlamp argument could not. While there are valid reasons for not requiring headlamps on all bicycles, as discussed above, the anti-headlamp argument could succeed only if the all-reflector system looked as though it adequately replaced the headlamp. To the ill-informed, with its all-round reflectors including its white front reflector, it indeed looked as though it did. The argument was made that the all-reflector system was cheap and maintenance-free, and that although it might not be quite as good as a proper headlamp system it was far better than a headlamp that had been installed at time of sale and had been neither used nor maintained since.

While there was a demonstration of the all-reflector system's effectiveness in reflecting headlamp light, no matter at what angle the bicycle was, there was no test or analysis at all of whether or not the headlamps would shine on the bicycle at the time a collision could be avoided. Maybe the designers and adopters of the system thought that it would, maybe they didn't consider the question at all, or maybe they knew it wouldn't but wanted it anyway; that is unknown. What is known is that nothing was done to analyze the probable effectiveness of the system in preventing nighttime car-bike collisions. By the time that I raised the question in my comments about the CPSC's regulation, it was too late for such comments to be seriously considered. Up to that time those who had the responsibility of experts in that field either thought that the all-reflector system would work or, at the worst possible interpretation, thought that their statements that it would work would be accepted by the courts and by society at large.

As it turned out, they were correct on both counts. The courts accepted their words, refusing to rescind the all-reflector system. "Reflectors appear to provide a significant margin of added safety at a relatively small monetary cost and loss in bicycle efficiency. In view of the Commission's careful balancing of the relevant factors, we do not find this standard to be irrational."[3]

The public also believes that the all-reflector system is an adequate substitute for the headlamp and rear reflector system. The court in Forester vs. CPSC agreed with the CPSC that the public would not believe this. "Forester's argument assumes that cyclists who ride at night would, but for the standard, purchase, maintain, and use headlamps. The Commission could rationally have concluded that this was unlikely; rather, that many unsophisticated or infrequent nighttime riders would otherwise do so without any protection at all."

The facts developed after twenty-five years of experience with the all-reflector system demonstrate the accuracy of my prediction and the inaccuracy of the CPSC's and the court's predictions. In the course of the Johnson vs. Derby case,[4] evidence was developed by the chairman of the department of psychology at Rutgers University that 85% of New Jersey high-school students believed that a bicycle with only the all-reflector system was safe to ride at night. The respondents who felt this way typically said that because the bicycle had all those reflectors it was safe to ride at night. The CPSC's own study of bicycle accidents[5] shows that only 1/3 of those who ride at night used either a headlamp or a rear lamp, and that 50% more people added a rear lamp to the existing rear reflector than used a headlamp. Of those people who thought enough about nighttime safety to buy a lamp, many more thought that the front reflector was an adequate substitute for the headlamp than thought that the rear reflector was adequate.

In summary, the evidence is very good that the all-reflector system persuades people that it is an adequate substitute for the headlamp.

8.2 The Bicycle Manufacturers' Solution

The position of the Bicycle Manufacturers Association was expressed at the last CPSC meeting on this subject. I quote from my report of that meeting.

"Michael Kershow, General Counsel of the Bicycle Manufacturers' Association, presented the view of BMA, largely regarding the liability question rather than discussing the safety aspects. The average bicycle sells for less than $100 at Walmart or Toys R Us. It is a good thing that 90% of customers don't ride at night, because nighttime cycling is too dangerous. These customers wisely choose not to ride at night. The industry must not supply lights as Original Equipment because that encourages cycling at night, which is very dangerous, and presents liability problems for bicycle manufacturers. We should actively discourage cycling at night because automobiles weigh 2,000 pounds. Here is his list of 8 actions.

1: Tell the public, "Don't ride at night," but continue to require reflectors and discourage their removal.
2: The all-reflector system is a very effective passive system that requires no activation by the user; not to be replaced by complicated lights.
3: If you ride at night, you must use both the all-reflector system and lights, because these are complementary elements (in some good design?).
4: We need standards for lights.
5: No OEM lights, because these would encourage nighttime cycling, while common sense now prevails on people not to cycle at night.
6: Lights are too expensive. The all-reflector system is appropriate because it provides a high degree of conspicuity at low cost.
7: Providing lights with bicycles does not guarantee that they will be used. The consumers are too dumb to maintain lights and to use them when needed.
8: Improve the enforcement of state laws and improve education."

There is a lot of good sense in this proposal, particularly about the policy and liability aspects, but its engineering is incorrect and its predictions about behavior don't fit the facts as they have developed.

I discuss the engineering errors first. The claim that the all-reflector system is very effective is false. The all-reflector system is ineffective against all bike-bike and bike-ped collisions. It is ineffective against the 79% of the car-bike collisions that are probably caused by darkness that come from the front or from diagonally to the front on intersecting streets or driveways.

The claim that the all-reflector system and the lights system are complementary elements of some undefined system is false. If the cyclist uses headlamp and rear lamp, the only part of the all-reflector system that has any function is the rear reflector, and then merely as a backup in case the rear lamp goes out. No part of the system can substitute for the headlamp, even as a backup, because no part of the system fulfills the functions of the headlamp, even poorly.

While the all-reflector system does provide considerable conspicuity, the engineering error is the false assumption that the conspicuity that is provided is useful in preventing car-bike collisions. For example, the bouncing wheel reflectors provide great conspicuity in many situations, which makes the ill-informed public think that they are great, but the conspicuity is there only when there is no possibility of collision, unless the cyclist is just standing in the middle of the road waiting to be hit.

The BMA is very insistent that people should not be tempted to ride at night. However, the BMA argues that while headlamps tempt people to ride at night, the all-reflector system does not tempt people to ride at night. Well, consider the facts. About 3/4 of the people who ride at night do so with the all-reflector system but without headlamps.[6] Whether the type of their nighttime equipment actually tempts people to ride at night is dubious, but the evidence is that the great majority of those who see the need to ride at night believe that the all-reflector system is adequate, and that the majority of those who do not believe that the all-reflector system is adequate believe that the significant inadequacy is in the rear reflector rather than in the front reflector.

8.2.1 Liability Aspects of the BMA's Solution

The case of Johnson vs. Derby Cycle Co. that shook the industry was decided before the last CPSC meeting about nighttime protective equipment, the meeting at which the attorneys for the industry presented their position. Other car-bike collisions have occurred as a result of relying on the all-reflector system and, inevitably, some of them will result in similar suits. Because the industry has publicly stated its position, it should be more afraid of those suits now than before the last meeting, because its recommendations are untenable.

The industry wants the all-reflector system because, so it says, that system provides a high degree of conspicuity at low cost and with minimum maintenance. The industry claims that cycling at night is dangerous. The industry prefers the all-reflector system because of the cost and probable liability associated with the lights that it would otherwise install, or be required to install. If a jury were presented with that evidence after it had seen the really indisputable evidence that the claimed high degree of conspicuity cannot have been present at the time and place necessary to prevent the collision being considered, and that a headlamp probably would have been seen, there is little doubt about what the jury would find.

8.3 The Better Solution

We need a system that fulfills two safety functions. It must:

1: Provide adequate conspicuity of the type that prevents collisions when used at night;

2: Clearly indicate that the bicycle with only the time of sale equipment is not safe to ride at night.

In addition to these two safety functions, the system must have three other characteristics. It must:

3: Be within the lawful authority of the CPSC;

4: Have the legal status to preempt local requirements at the time of sale;

5: Satisfy the need for liability protection of the manufacturers who must use it.

A system that meets these requirements can be readily available. In this system the CPSC requires only a rear reflector at time of sale and the states require both that rear reflector and a headlamp whenever the bicycle is used at night. The CPSC also specifically requires that the manufacturer provide the instruction that a headlamp must also be used for safety when cycling at night. The combination fulfills the two safety requirements.

1: It clearly provides the necessary equipment for cycling at night.

2: The presence of only the rear reflector at time of sale removes any temptation to believe that the bicycle, as sold, is properly equipped for cycling at night.

The combination also fulfills the other three characteristics.

3: Requiring a reflector on all bicycles sold is clearly within the scope of the CPSC's authority. Not having a requirement for a headlamp on all bicycles sold means that the CPSC has not issued a requirement with a very poor benefit/cost ratio and that would produce liability problems for the manufacturers who had to comply.

4: The purpose of the required rear reflector is to reduce the frequency of nighttime car-bike collisions, and that is the only purpose that reflectors serve. Therefore, no local authorities could require other or different reflectors at the time of sale.

5: Because the reflector obviously serves only to the rear, it is patently obvious that something else is required for protection from the front, both directly and diagonally. There is no additional equipment that could tempt the user to conclude that the bicycle was suitable for nighttime cycling. There is nothing that even looks as though it fulfilled the function of a headlamp.

8.4 Equipment Details

8.4.1 Reflector

The rear reflector should be as bright as practical over the required angular range. The present CPSC reflector is far from optimum. First, because its design philosophy was all-around protection, which is not necessary, only 1/3 of its area would reflect at any one angle. The SAE design of reflector reflects over about 20 degrees on each side of the center line, which is sufficient. Therefore, the entire area of the new reflector can reflect over the required range. That multiplies the brightness by three times. The present reflector is red, a color that reflects white light only dimly. An amber reflector is 2.5 times brighter than a red reflector of the same size. (A white reflector is 4 times brighter than a red reflector.) The rear reflector should be amber. This is not standard for the rear of a vehicle, but it is standard for roadway obstructions such as construction areas. Since in most cases the bicycle will be moving much slower than the overtaking motor vehicle, the motorist will take the same precautions whether he sees a red reflector or an amber one. In fact, amber may be safer than red of equivalent brightness. The amber will prevent the motorist from thinking that the vehicle ahead is moving fast and that he has more time to take the proper action than he actually has. White, while brighter still, indicates an oncoming vehicle and should not be used because it might cause confusion.

Combining the increase in active area and the change to amber would increase the brightness of the reflector by more than 7 times more than that now specified, for the same size reflector. This is well worth the change.

8.4.2 Headlamp Accessories

While the CPSC cannot reasonably require headlamps, it can offer interface standards that facilitate the use of lamps.

A great many lamps have been designed to use a standard bracket, which is 30 mm square and 3 mm thick. Each lamp has a socket at its back that fits over the bracket. These brackets are available in a variety of shapes that fit to different parts of the bicycle: handlebars, steering column, front fork blades, etc., as required by the type of bicycle and the desires of the user. The CPSC can reasonably specify a standard bracket and require that each headlamp manufacturer either provide a complete mounting for his headlamp or a socket to match the standard. The more manufacturers that match the standard the simpler it will be to mount lamps and replace broken ones.

A similar problem exists for generator mountings. The typical generator mounting combines the worst features of being neither permanent nor removable, and it scratches the paint and tends to come dangerously loose as well. There have been permanent generator brackets, but none became standard because of the variety of dimensions encountered. A system with sufficient adjustability has a standard bracket permanently fixed to the bicycle's frame, either front fork blade or rear stay, parallel to the center line of the bicycle, with two 5 mm holes 30 mm apart, approximately vertically spaced and about 100 mm below the tire contact point. These are the only specified interface dimensions. An intermediate adjustable plate bolts onto the standard bracket and carries the generator in the proper position and, for front fork mounting and if the user desires, carries the headlamp also in one simple removable unit. The simplest adjustable plate is made of soft aluminum that can be easily bent to place the generator at the correct lateral distance from the tire, drilled to hold the generator at the proper position, and finally trimmed to size.

Provision of standard interface dimensions for these items would promote the easy use of proper headlamps without requiring any special equipment at time of sale.

End Notes

1 Cross, Kenneth D., and Gary Fisher; *A Study of Bicycle/Motor-Vehicle Accidents: Identification of Problem Types and Countermeasure Approaches*; National Highway Traffic Safety Administration; 1977

2 Forester, John; *Bicycle Transportation* 2nd ed.; The MIT Press, 1994; chap 5, chap 17

3 Forester vs. CPSC, 75-1292, Court of Appeals for the District of Columbia

4 Johnson vs. Derby, Essex County Superior, NJ, 1993

5 Bicycle Use and Hazard Patterns in the United States; U.S. Consumer Product Safety Commission; 1994

6 The all-reflector system has been on most bicycles sold in the U.S.A. for 25 years. The data in the CPSC's study indicate that about 3/4 of nighttime cyclists do not use a headlamp.