REPORT UM-HSRI-HF-TM-74-6

DEVELOPMENT OF A COMPUTER PROGRAM TO DERIVE THE INTENSITIES AND ILLUMINATION LEVELS OF HEADLAMP BEAMS IN REARVIEW MIRRORS

Judith M. Becker

Highway Safety Research Institute
The University of Michigan
Ann Arbor, Michigan 48105

January 28, 1974

Sponsored by:

Donnelly Mirrors, Inc., Holland, Mich. (Project 300346), and The Motor Vehicle Manufacturers Association of the U.S., Inc., Detroit, Mich. (Project 360763).

OBJECTIVES

In addition to the glare from the headlights of opposing traffic, there is glare from the headlights of following traffic as reflected in rearview mirrors. The purpose of this program is to derive the intensities directed at the driver's eye from those following headlamps via his own mirrors and the resulting illumination levels at his eye. Also derived is the glare angle of each headlamp image in each mirror relative to an eye line-of-sight looking straight ahead.

PROCEDURE

The origin for the input to this program is at the center of the vehicle, on the road, in the plane of the main headlamps. The X-axis is positive forward (ahead of the vehicle), the Y-axis is positive up and the Z-axis is positive to the right. Some of the input data do not follow these conventions as to sign, but are input positive when they are in their most probable position: e.g., the longitudinal distance from the eye to the origin is positive because the eye is normally behind the lamps. Some of the data is not referenced to the origin but to the eye, notably the data for the following reference lamp. Mirror reflectivities, rear windshield transmissivity and following headlamp filters (both less than and greater than one) are also inputs.

The mirrors can be aimed and dimensioned by the program according to the field-of-view desired at some specified distance behind the driver. Rectangular mirrors are done in both dimensions, while circular mirrors are computed for the lateral direction and centered in the vertical direction. An alternate method allows the user to specify the mirror dimensions and to aim the center point of the mirror at any desired point at some specified distance behind the driver.

After the main vehicle data has been read in and the mirror angles and other parameters computed, come the cards describing the following vehicle lamps. Each lamp can be misaimed in three directions: up and down, right and left and around. As each one is read, the position of the lamp image on each mirror is calculated. If the image is outside the dimensions of the mirror, it is ignored. If the line from the lamp to its image pierces the obstructing plane (located at the rear of the main vehicle and simulating its solid portion), it is also ignored. If the image is to be used, then its horizontal and vertical angles in the lamp's beam pattern are calculated and the intensity in that direction is found by a double linear interpolation on the logarithm of the intensity values. The illumination level is calculated by dividing this intensity value by the square of the total distance from the eye to the lamp. Then the glare angle of the image relative to the eye looking straight ahead is calculated and the data printed out. This is done for each desired following distance.

Finally, after all the following lamps have been taken care of, the intensities and illumination levels are summed over the lamps for each mirror and that data printed out.

EVALUATION OF SOME EXISTING AND PROPOSED BEAMS

In order to check out the program it was decided to run it on some existing and proposed beams. The beam patterns used for the existing beams were taken from photometry data on a W 6014 low and high beam and a GE type-3 mid beam. The proposed beams were those in the government docket #69-19, described as type 3 low and high, type 4 middle and type 5 high, for both minimum and maximum allowed intensity values.

The field-of-view of the interior mirror covered section Q of the government target* in docket #71-3a, while that of the

*See Figure 1.

exterior mirror included half of section SL and one-fourth of section Q. It would have been better to use slightly more of section Q as this choice, when combined with the positions of the mirror and eye, led to the cone-of-view angling slightly outward. Thus, for distance quite far behind the main vehicle, but within the range of interest, the passing lane was not included in the exterior mirror's field-of-view in this example.

The following vehicle was positioned first in the same lane and then in the passing lane, at distances varying from 50 to 2000 feet. In the same lane case all the lamps were visible in the interior mirror and none in the exterior. In the passing lane case, all the lamps were visible in the interior mirror, except at 50 feet. All the lamps were visible in the exterior mirror until the cone-of-view moved too far to the left, at about 900 feet.

DESCRIPTION OF INPUT

The input cards all have the same layout or format, except for the card which immediately follows the T card. This format consists of a letter for identification in column one, a real number in columns two through ten, and seven more real numbers in the next seven groups of ten columns each. In programming terms, this format is described as: A1, E9.0, 7E10.0. It does not matter where in the group of nine or ten columns the decimal point appears, but it must be present. A group of columns is called a field, and they are numbered for easy reference consecutively from one to eight across the card. Thus, field one has nine columns, while fields two through eight each have ten columns. Each input card can thus contain up to eight pieces of input data, the nature of which is determined by the identification letter, referred to as ID. For each field of each card there is given in Table 1 the definition of the piece of input data, its default value (if any) and its units (if pertinent). The default value is the value the datum will have if the user does not specify a value.

TABLE 1

ID	Field	Definition	Default Value	Units
K	1	Number of following distance points	40	Feet
	2	Distance between points	-	Feet
	3	First following distance	-	Feet
	4	Transmissivity of rear windshield	1	-
	5	Debug level	0	-
	6	Not used		
	7	Tolerable error in mirror field-of-view, fraction	-	-
	8	Number of subsequent data sets expected	0	-
V	1	Distance from headlamp plane to obstructing plane	-	Inches
	2	Distance from road to top of obstructing plane	-	Inches
	3	Distance from center of vehicle to right side of plane	-	Inches
	4	Z-distance of left side of plane from origin	-	Inches
	5	Distance from headlamp plane to eye	-	Inches
	6	Distance from road to eye	-	Inches
	7	Distance from center of vehicle to eye	-	Inches
H	1	Lamp index	-	-
	2	Filter value	1	-
M	1	Mirror index: 1=interior, 2=exterior	-	-
	2	Distance from headlamp plane to mirror	-	Inches
	3	Distance from road to mirror	-	Inches
	4	Z-distance of mirror from origin	-	Inches
	5	Reflectivity of mirror	1	-
	6	Shape indicator: 0=circular, positive=rectangular	-	-
O	1	Mirror index: 1=interior, 2=exterior	-	-
	2	Lateral dimension of mirror	-	Inches
	3	Vertical dimension of mirror	-	Inches
	4	Distance from road to mirror center aim point	-	Inches
	5	Z-distance of mirror center aim point from origin	-	Inches
	6	Distance from eye to mirror center aim point	30	Feet

TABLE 1 (concl.)

F	1	Mirror index: 1=interior, 2=exterior	-	-
	2	Distance from road to bottom of field-of-view	-	Inches
	3	Distance from road to top of field-of-view	-	Inches
	4	Distance from center of vehicle to right side	-	Inches
	5	Z-distance of left side from origin	-	Inches
	6	Distance from eye to plane of field-of-view	30	Feet
T		None; triggers reading of title card. Title may be 80 characters long, including spaces and should be centered on the card		
D	1	Lamp index, M	-	-
	2	X-distance from reference lamp to lamp #M	-	Inches
	3	M=1: distance from road to reference lamp M=2-5: Y-distance from reference lamp to lamp #M	-	Inches
	4	M=1: distance from center of vehicle to reference lamp M=2-5: Z-distance from reference lamp to lamp #M	-	Inches
	5	Vertical misaim angle, positive up	-	Degrees
	6	Horizontal misaim angle, positive to right	-	Degrees
	7	Rotational misaim angle, positive clockwise	-	Degrees
	8	Index of beam pattern in disk file	-	-
Z		None		

Notes:

1) Cards should be in this order for best results:

   K V H M O F T D Z

2) Cards O and F should not be used in the same data set.

3) Card H should be omitted unless the beam pattern is to be modified.

4) For multiple data sets (i.e., card K field 8 greater than 0), any card on which the data is the same as in the preceeding data set may be omitted.

5) Cards M and either O or F form a set (i.e., both cards for index 1 should be before both cards for index 2).

Before this program can be run, the beam patterns to be used must be written into a disk file by a separate program.

The first input data card specifies the number of beam patterns to be written into the disk file. A maximum of ten may be done at one time; i.e., the disk file is large enough to hold ten different beam patterns. Five columns are allowed for this number, which is an integer. Thus, for one through nine different beam patterns, the appropriate integer appears in column five. For ten, put a "1" in column four and a "0" in column five. Then comes a card describing the beam pattern, as follows: first, the index of the beam (1 through 10) in the first five columns (integer, as above); second, the number of horizontal angle points in the beam pattern, with a maximum value of 61 in columns 6-10 (integer); third, the number of vertical angle points, with a maximum value of 22 in columns 11-15 (integer); fourth, the value of the leftmost (most negative) horizontal angle in degrees (real) in columns 16-20; fifth, the value of the lowest (most) negative) vertical angle in degrees (real) in columns 21-25; sixth, the value of the angle increment (degrees real) in columns 26-30; seventh, a description in words of the beam pattern in columns 31-72; eighth, the value of any constant filter factor to be applied across the beam as a decimal fraction (real) in columns 73-80. Then come the cards bearing the values of the beam pattern headlight intensity for the various angle pairs. Starting with the leftmost horizontal angle, there will be one or two cards giving the intensity values in candelas for each vertical angle, starting with the lowest. The intensity values are real numbers with decimal points occupying seven columns each across the card. Thus, there will be eleven values on the first card, with three columns unused at the end, and the same on the second. Each horizontal angle has its own pair of cards.

DESCRIPTION OF OUTPUT

The output for a run consisting of several data sets starts with one page of general input data. On this page there is a general title and the date. Then the data for the following vehicle distances is printed, as is the rear windshield transmissivity. The main vehicle structure is included as an obstructing plane located in the trunk region. Its dimensions are given next. Then the location of the driver's eye relative to the origin is printed. Next comes the mirror data with its center point location and aim being given relative to the eye. Note that for a round mirror, height is equal to width. Next are the print-outs of the desired field-of-view for each mirror, which defines the mirror orientation and size, if card F is used.

Then comes the output data for each lamp of the following vehicle, generally one page per lamp. At the top of the page is the general title, date and page number. Then comes the data describing the lamp: location, misaim and name of beam pattern used. Then the intensity, illumination, glare angle and angles in beam pattern of this lamp for each mirror are printed for each following distance.

The last page for each data set is a summary of intensity and illumination for each mirror summed over all the lamps.

For the next data set, the page of general input data will be omitted if nothing is changed. If any of this data is different, however, it will be printed out as described above. Then the output pages will follow.

The output for one of the runs from the evaluation of existing and proposed beams is given in Figure 2.

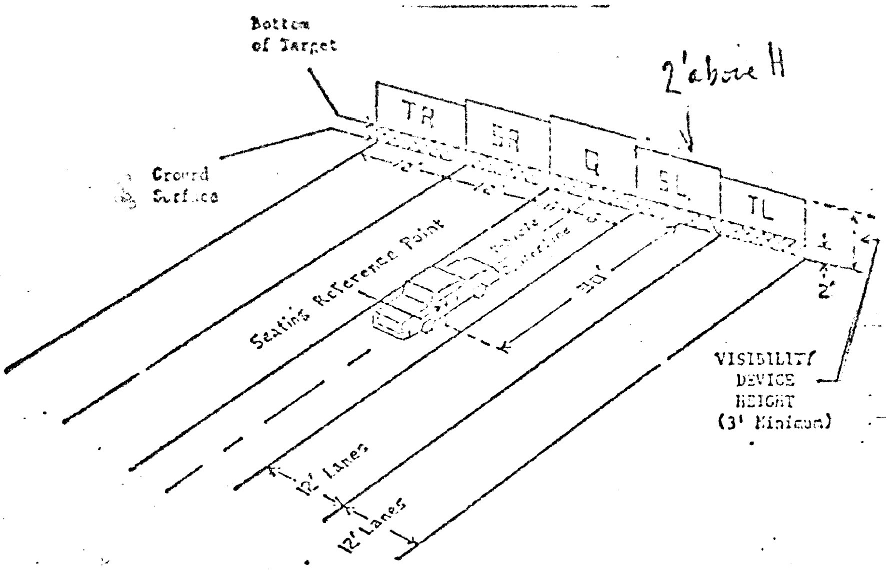

Figure 1. PICTORIAL EXAMPLE SHOWING PLACEMENT OF THE FIVE VERTICAL TARGETS WITH RESPECT TO THE PASSENGER CAR CENTERLINE AND THE SEATING REFERENCE POINT

MIRROR GLARE FOR FOLLOWING VEHICLES   31-JAN-74   PAGE

NO. OF POINTS IS 10 AT 50.0 FEET APART STARTING AT 50.0 FEET BEHIND EYE. TRANSMISSIVITY OF REAR WINDSHIELD IS 1.0000

OBSTRUCTING PLANE IS 154.0 INCHES BEHIND LAMPS, TOP IS 37.0 INCHES ABOVE ROAD, EDGES ARE 32.0 AND -32.0 INCHES FROM LANE CENTER.
EYE IS 106.0 INCHES BEHIND LAMPS, 46.0 INCHES ABOVE ROAD AND 15.0 INCHES FROM LANE CENTER

MIRROR	TYPE	LOCATION (INCHES)			SIZE (INCHES)		ORIENTATION (DEGREES)			CENTER POINT AIM			
NUMBER		X	Y	Z	WIDTH	HEIGHT	YAW	PITCH	ROLL	X	Y	Z	REFLECTIVITY
1	INTERIOR	22.0	2.0	15.0	9.8	2.4	-16.81658	2.7[illegible]050	0.82186	-360.0	-4.0	19.0	1.0000
2	EXTERIOR	17.0	-6.0	-22.0	8.5	8.5	21.54328	-7.1[illegible]886	0.00000	-360.0	-5.1	-78.0	1.0000

INTERIOR MIRROR FIELD OF VIEW AT 30.0 FEET BEHIND EYE, 24.0 TO 60.0 INCHES ABOVE ROAD, -72.0 TO 72.0 INCHES FROM LANE CENTER

EXTERIOR MIRROR FIELD OF VIEW AT 30.0 FEET BEHIND EYE, 24.0 TO 60.0 INCHES ABOVE ROAD, -144.0 TO -36.0 INCHES FROM LANE CENTER

Figure 2. Example of output.

MIRROR GLARE FOR FOLLOWING VEHICLES 31-JAN-74 PAGE 1

W. 6014 HIGH, NOMINAL SAME LANE TRUCK MOUNT

DISTANCE BETWEEN HEADLIGHT NO. 1 AND EYE (IN.) X 106.00 Y 6.00 Z 12.00

MISAIM ANGLES (DEGREES) INDEX 1 VERT. 0.0 HOR. 0.0 ROT. 0.0

BEAM PATTERN INDEX 1 NAME W. 6014 HIGH (36,330 AT .5 R .5 D)

OUTPUT DATA FOR INTERIOR MIRROR FOR LAMP NO. 1

VEHICLE FOLLOWING DISTANCE (FEET)	INTENSITY DIRECTED AT MIRROR (CANDELAS)	ILLUMINATION AT EYE (FOOT CANDLES)	GLARE ANGLE RELATIVE TO X-AXIS (DEGREES)	ANGLES IN BEAM PATTERN (DEGREES) HOR.	VERT.
50.0	0.1772E 05	0.6057E 01	31.6	2.36	0.74
100.0	0.2632E 05	0.2427E 01	32.9	1.23	0.39
150.0	0.2930E 05	0.1234E 01	33.2	0.83	0.26
200.0	0.3047E 05	0.7315E 00	33.4	0.63	0.20
250.0	0.3118E 05	0.4831E 00	33.5	0.50	0.16
300.0	0.3163E 05	0.3421E 00	33.6	0.42	0.13
350.0	0.3194E 05	0.2546E 00	33.7	0.36	0.11
400.0	0.3217E 05	0.1970E 00	33.7	0.32	0.10
450.0	0.3234E 05	0.1569E 00	33.8	0.28	0.09
500.0	0.3248E 05	0.1276E 00	33.8	0.25	0.08

OUTPUT DATA FOR EXTERIOR MIRROR FOR LAMP NO. 1

VEHICLE FOLLOWING DISTANCE (FEET)	INTENSITY DIRECTED AT MIRROR (CANDELAS)	ILLUMINATION AT EYE (FOOT CANDLES)	GLARE ANGLE RELATIVE TO X-AXIS (DEGREES)	ANGLES IN BEAM PATTERN (DEGREES) HOR.	VERT.
50.0	0.0000E 00	0.0000E 00	0.0	0.00	0.00
100.0	0.0000E 00	0.0000E 00	0.0	0.00	0.00
150.0	0.0000E 00	0.0000E 00	0.0	0.00	0.00
200.0	0.0000E 00	0.0000E 00	0.0	0.00	0.00
250.0	0.0000E 00	0.0000E 00	0.0	0.00	0.00
300.0	0.0000E 00	0.0000E 00	0.0	0.00	0.00
350.0	0.0000E 00	0.0000E 00	0.0	0.00	0.00
400.0	0.0000E 00	0.0000E 00	0.0	0.00	0.00
450.0	0.0000E 00	0.0000E 00	0.0	0.00	0.00
500.0	0.0000E 00	0.0000E 00	0.0	0.00	0.00

DISTANCE BETWEEN HEADLIGHT NO. 1 AND NO. 2 (IN.) X 0.00 Y 0.00 Z 54.00

MISAIM ANGLES (DEGREES) INDEX 2 VERT. 0.0 HOR. 0.0 ROT. 0.0

BEAM PATTERN INDEX 1 NAME W. 6014 HIGH (36,330 AT .5 R .5 D)

OUTPUT DATA FOR INTERIOR MIRROR FOR LAMP NO. 2

VEHICLE FOLLOWING DISTANCE (FEET)	INTENSITY DIRECTED AT MIRROR (CANDELAS)	ILLUMINATION AT EYE (FOOT CANDLES)	GLARE ANGLE RELATIVE TO X-AXIS (DEGREES)	ANGLES IN BEAM PATTERN (DEGREES) HOR.	VERT.
50.0	0.1263E 05	0.4313E 01	36.3	-2.41	0.74
100.0	0.2355E 05	0.2174E 01	35.2	-1.25	0.39
150.0	0.2692E 05	0.1130E 01	34.9	-0.85	0.26
200.0	0.2840E 05	0.6821E 00	34.7	-0.64	0.20
250.0	0.2938E 05	0.4552E 00	34.5	-0.51	0.16
300.0	0.3002E 05	0.3207E 00	34.5	-0.43	0.13
350.0	0.3049E 05	0.2432E 00	34.4	-0.37	0.11
400.0	0.3085E 05	0.1889E 00	34.4	-0.32	0.10
450.0	0.3113E 05	0.1510E 00	34.3	-0.29	0.09
500.0	0.3136E 05	0.1234E 00	34.3	-0.26	0.08

OUTPUT DATA FOR EXTERIOR MIRROR FOR LAMP NO. 2

VEHICLE FOLLOWING DISTANCE (FEET)	INTENSITY DIRECTED AT MIRROR (CANDELAS)	ILLUMINATION AT EYE (FOOT CANDLES)	GLARE ANGLE RELATIVE TO X-AXIS (DEGREES)	ANGLES IN BEAM PATTERN (DEGREES) HOR.	VERT.
50.0	0.0000E 00	0.0000E 00	0.0	0.00	0.00
100.0	0.0000E 00	0.0000E 00	0.0	0.00	0.00
150.0	0.0000E 00	0.0000E 00	0.0	0.00	0.00
200.0	0.0000E 00	0.0000E 00	0.0	0.00	0.00
250.0	0.0000E 00	0.0000E 00	0.0	0.00	0.00
300.0	0.0000E 00	0.0000E 00	0.0	0.00	0.00
350.0	0.0000E 00	0.0000E 00	0.0	0.00	0.00
400.0	0.0000E 00	0.0000E 00	0.0	0.00	0.00
450.0	0.0000E 00	0.0000E 00	0.0	0.00	0.00
500.0	0.0000E 00	0.0000E 00	0.0	0.00	0.00

Figure 2 (cont.)

W. 6014 HIGH, NOMINAL SAME LANE TRUCK MOUNT

OUTPUT DATA FOR ALL LAMPS SUMMED

	INSIDE MIRROR		OUTSIDE MIRROR	
VEHICLE FOLLOWING DISTANCE (FEET)	INTENSITY DIRECTED AT MIRROR (CANDELAS)	ILLUMINATION AT EYE (FOOT CANDLES)	INTENSITY DIRECTED AT MIRROR (CANDELAS)	ILLUMINATION AT EYE (FOOT CANDLES)
50.0	30348.5	0.1037E 02	0.0	0.0000E 00
100.0	49846.1	0.4601E 01	0.0	0.0000E 00
150.0	56220.8	0.2368E 01	0.0	0.0000E 00
200.0	58869.7	0.1414E 01	0.0	0.0000E 00
250.0	60567.9	0.9383E 00	0.0	0.0000E 00
300.0	61651.0	0.6668E 00	0.0	0.0000E 00
350.0	62427.1	0.4980E 00	0.0	0.0000E 00
400.0	63214.3	0.3666E 00	0.0	0.0000E 00
450.0	63474.1	0.3279E 00	0.0	0.0000E 00
500.0	63844.1	0.2513E 00	0.0	0.0000E 00

Figure 2 (concl.).