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VALIDATION AND EXTENSION OF VISIBILITY REQUIREMENTS ANALYSIS FOR UNDERGROUND MINING EQUIPMENT

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16. Abstract (Limit: 200 words) Six underground coal mine shuttle cars (three high seam and three low seam) were used to assess visibility using the concept of visual attention locations (VALs) and an improved human eye reference measurement instrument (HERMI Mark II). Each machine was assessed in the inby and outby direction of travel with no canopy and with the canopy in its highest and lowest position. In addition, the illumination level at each VAL was determined.

Results showed that the most important variable determining visibility was operator eye position. When this variable is controlled, the addition of a canopy has no effect on visibility. Further, with eye position controlled, there is no difference in visibility between high and low seam machines.

The visibility and illumination assessments found blind spots in the operator's field of view located on the opposite side of the car from the operator and ahead of the machine. Suggestions for reducing the blind spots were made.

The report also included a procedure manual for using HERMI and the system of VALs to assess visibility from underground shuttle cars, continuous miners, and scoops.

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Visibility	Coal Mining	Visual Attention Locations
Illumination	Shuttle Cars	Canopy
Underground	HERMI	Seam Height
		Eye Position

b. Identifiers/Open-Ended Terms

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FOREWORD

This report was prepared by Canyon Research Group, Inc., Westlake Village, California under USBM Contract number J0318072. The contract was initiated under the Coal Mine Health and Safety Program. It was administered under the technical direction of the Pittsburgh Research Center with Mr. James M. Peay acting as Technical Project Officer. Mr. William Mundorf was the contract administrator for the Bureau of Mines. This report is a summary of the work recently completed as a part of this contract during the period 1981 to 1982. This report was submitted by the authors in January 1983.

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1.0 INTRODUCTION

1.1 Background

This project is a validation and extension of research carried out by Canyon Research Group, Inc. (Sanders and Kelley, 1981; Sanders, 1981) under contract No. J0387213. That original research determined visibility requirements for shuttle car and continuous miner operations. In addition, a methodology was developed to assess the actual field of visibility from these machines in relation to the visibility requirements identified.

The visibility requirements (what the operator needed to see) were determined using a task analytic approach. The job was divided into tasks. For each task, operators were asked what information was required to do the task (information requirements). For each information requirement, specific visual features which served as sources of the information were identified. The location of each visual feature in the visual field was determined. From this information, visual requirements in the form of a list of visual attention locations (VALs), were developed. A VAL is defined as a location, described in relation to machine points (front edge, highest point, etc.), wherein one or more important visual features need to be seen to operate the equipment safely and efficiently. A complete discussion of this process can be found in Sanders and Kelly (1981) and a summary of the process can be found in Sanders (1981).

The method developed to assess the field of visibility (what the operator can see) involved the use of a human eye reference measurement instrument (HERMI). HERMI simulates the eye positions of a 5th percentile female and a 95th percentile male in a sitting or reclined posture with reasonable neck and torso flexion. HERMI is positioned in the equipment cab and pictures are taken of the cab from each of the VALs. If HERMI can be seen from the VAL, then an operator in the position of HERMI could see the VAL. The methodology is simple, and provides a photographic record of obstructions which block HERMI's view of the VAL.

The original HERMI developed by Sanders and Kelley (1981) was made of foam-core board and had several shortcomings as discussed by Sanders (1981). First, it was not ruggedly constructed. Second, the 5th percentile female eye ring could not be positioned independently of the 95th percentile male eye ring. Third, it did not take into account clearance requirements between the eyes and the top of the canopy needed to accommodate the hardhat of the operator.

The concept of VALs and the use of HERMI have received considerable attention by SAE Subcommittee 29 in their draft human factors guidelines for underground mining equipment.

1.2 Purpose

The purpose of this project was to validate and extend the methodologies developed by Sanders and Kelley. Shuttle cars were chosen as the focus because of their mobility in the mine and the consequences of their having an inadequate visual field. Four objectives were defined:

1. Redesign and fabricate an improved HERMI (Mark II) which overcomes the shortcomings of the original HERMI.

2. Assess the field of visibility of a sample of shuttle cars to determine which VALs are not visible, and to assess the effects of a canopy and its height on visibility.

3. Measure the illumination from machine lights for a sample of shuttle cars at each VAL to assess the adequacy of current shuttle car illumination systems with respect to the system of VALs.

4. Reassess the original set of shuttle car VALs in view of the information collected to determine if some of the VALs can be eliminated without affecting the efficiency or safety of operation.

1.3 Organization of Report

This report is organized into four major sections in addition to this introductory section. Section 2.0 presents the methodology and results of the assessment of the field of visibility for a sample of six shuttle cars. In this chapter, the effect of a canopy, and the height of the canopy on visibility are assessed.

Section 3.0 presents the methodology and results of the illumination measurements made at the VALs.

Section 4.0 reevaluates the shuttle car VALs in light of the results presented in Sections 2.0 and 3.0. Recommendations for changing the list of VALs are made.

Section 5.0 is an instruction manual for assembling HERMI (Mark II) and assessing the fields of visibility for underground equipment. Included are complete lists of VALs for shuttle cars, continuous miners and scoops insofar as scoops are used to load, transport, and dump coal.

2.0 SHUTTLE CAR VISIBILITY

2.1 Method

2.1.1 Shuttle car sample. A total of six shuttle cars were evaluated. Half were low seam cars and half high seam cars. Three manufacturers, Joy, National Mine Service, and FMC, supplied cars for evaluation. The cars were selected on an "as available" basis. The cars were not selected to represent either unusually good or unusually bad designs. It is believed that the sample is representative of shuttle cars currently being marketed. All cars in the sample were assessed at the manufacturers' facilities. Table 2.1 presents pertinent data regarding the six cars used in this study. It must be pointed out, however, that shuttle cars are often customized for particular buyers. Thus, the particular cars used in this study, while representative, cannot be considered an exhaustive sample, even of the particular models included.

Table 2.1. Description of Shuttle Cars Evaluated

CODE	INTENDED SEAM HEIGHT (in.)	--- OVERALL DIMENSIONS --- MAX HEIGHT (in.)	LENGTH (in.)	WIDTH (in.)	OPERATOR POSITION
H1	>48	49	320	123	Center
H2	>48	64	327	110	End
H3	>48	77	334	109	End
L1	<48	45	300	136	Center
L2	<48	34	332	132	End
L3	<48	48	308	115	Center

2.1.2 HERMI Mark II. The Human Eye Reference Measurement Instrument (HERMI Mark II) pictured in Figure 2.1 was used to evaluate the visibility from the operator's cab. Section 5.0 of this report describes the rationale behind, and the construction of, HERMI. The two eye arcs shown in Figure 2.1 represent the 5th percentile female and 95th percentile male eye position given reasonable neck and torso flexion. HERMI was positioned in the cab to simulate the eye positions of a seated operator.

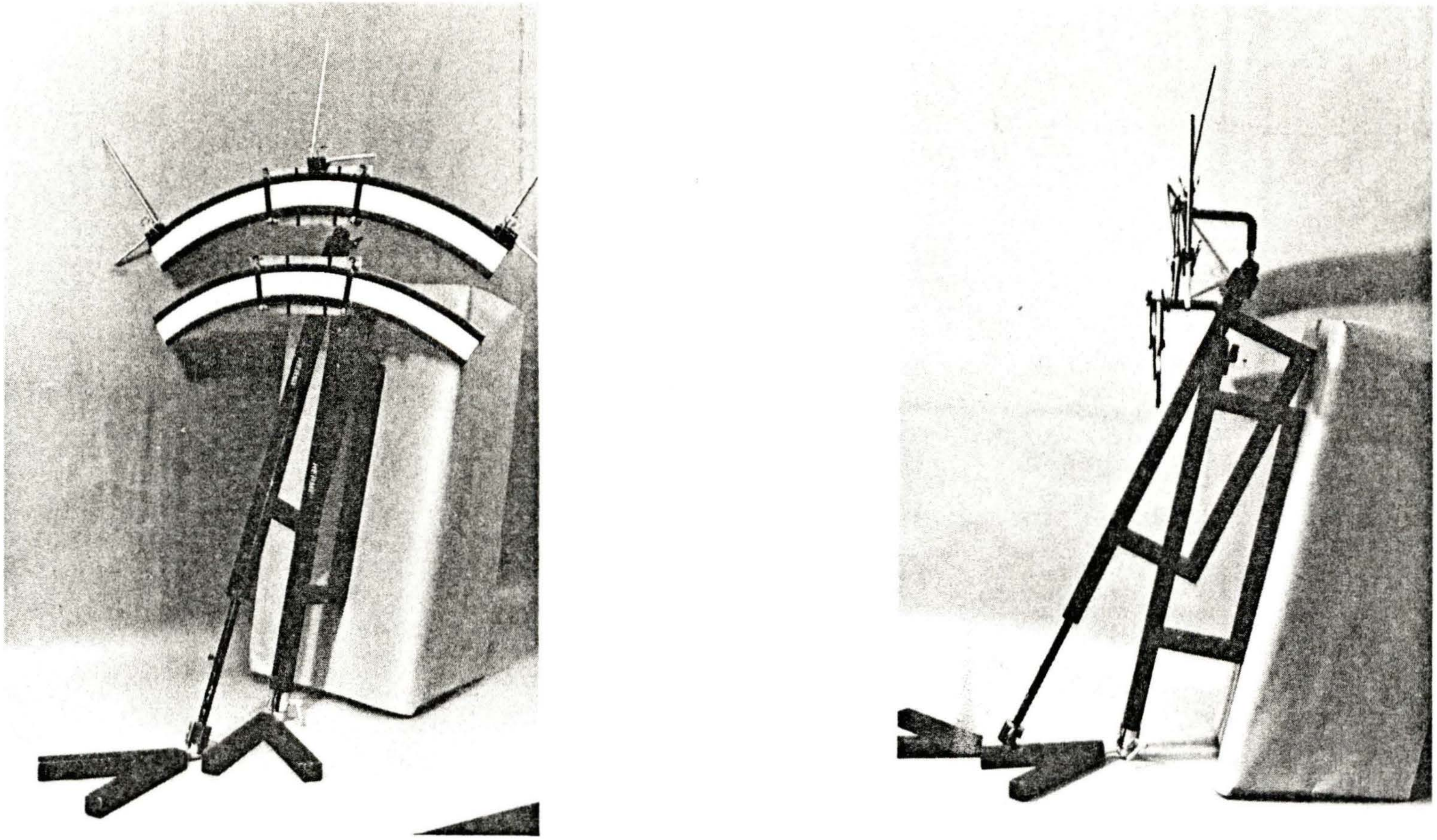


Figure 2.1. HERMI (Mark II) used to assess visibility.

2.1.3 Visual Attention Locations (VALs). Visual Attention Locations are locations at which one or more important visual features, which the operator needs to see in order to operate the equipment in a safe and efficient manner, are located. These locations were determined using a task analytic approach described by Sanders and Kelley (1981). A total of 54 VALs were identified for shuttle cars. Each VAL is defined as a point in three-dimensional space. Each is specified by a fore-aft, vertical (up-down), and lateral (side-to-side) measurement. The measurements are given in relation to machine reference points, such as the front edge, widest machine point, and highest machine point. A complete list of VALs appears in Section 5.0 of this report and in Section 2.2 along with the visibility results.

2.1.4 Procedure. Visibility was assessed according to the procedure presented in Section 5.0 of this report. Essentially, HERMI is positioned in the cab, and a picture of the cab is taken at each VAL. If the eye rings of HERMI are visible in the picture, then an operator in the position of HERMI could see the VAL. Visibility was assessed in the outby direction of travel for all cars, and in addition, in the inby direction for end driven cars. In each of these directions, visibility was assessed with the canopy off the machine, with it in its highest position, and with it in its lowest position. One car (L2) had a fixed canopy and, therefore, only one canopy position (low) was measured.

2.2 Results

2.2.1 Scoring. A simplified procedure for assessing visibility was used. A VAL was considered visible if any part of HERMI's eye rings were visible from the VAL. In only five to eight of the VALs was one eye ring visible while the other was not. In addition, no attempt was made to differentially weight visibility by whether torso flexion was required. Any system of differential weighting makes it possible to compensate lack of visibility from one car or VAL with "excellent" visibility from another. For this reason, a simple go-no-go decision was adopted. The procedure allows the direct computation of the percentage of cars from which an operator can see a particular VAL, or the percentage of VALs visible from a car.

2.2.2 Data set. The data set can be conceptually organized according to five variables:

Seam Height of Car (low versus high)
Type of Car (center versus end driven)
Direction of Travel (inby versus outby)
Canopy Condition (none versus low versus high)
HERMI Eye Position (low versus high)

With the canopy in place, HERMI's eye position is determined by the canopy height (i.e., low or high). With no canopy, however, HERMI can be positioned as if there were either a low canopy or a high canopy. Table 2.2 presents the data set and indicates sample sizes for each subset of data. These sample sizes include both inby and outby data for center driven cars, which is assumed to be identical.

Table 2.2. Organization of Data Set and Associated Sample Sizes

SEAM HEIGHT	TYPE OF CAR	DIRECTION OF TRAVEL	CANOPY	HERMI EYE POSITION	SAMPLE SIZE
Low	Center	Inby	None	Low	1
				High	1
			Low	Low	2
			High	High	2
		Outby	None	Low	1
				High	1
			Low	Low	2
			High	High	2
	End	Inby	None	Low	1
				High	0
			Low	Low	1
			High	High	0
		Outby	None	Low	1
				High	0
			Low	Low	1
			High	High	0
High	Center	Inby	None	Low	0
				High	1
			Low	Low	1
			High	High	1
		Outby	None	Low	0
				High	1
			Low	Low	1
			High	High	1
	End	Inby	None	Low	2
				High	0
			Low	Low	2
			High	High	2
		Outby	None	Low	1
				High	1
			Low	Low	2
			High	High	2

As can be seen in Table 2.2, some combinations were not measured, some combinations have two sets of data, and some only one set. Thus, to explore the effects of these variables, and their interactions, subsets of the data will be used to control for the other variables not involved in the particular analysis.

Before discussing the results of the visibility assessment by individual VALs, each of the major variables (i.e., center versus end driven, direction of travel, canopy, machine height, and HERMI eye position) will be discussed. As a summary measure of visibility, the total number of VALs visible for a particular machine configuration and direction of travel was computed. Using this total visibility measure, the effects of the various variables were assessed.

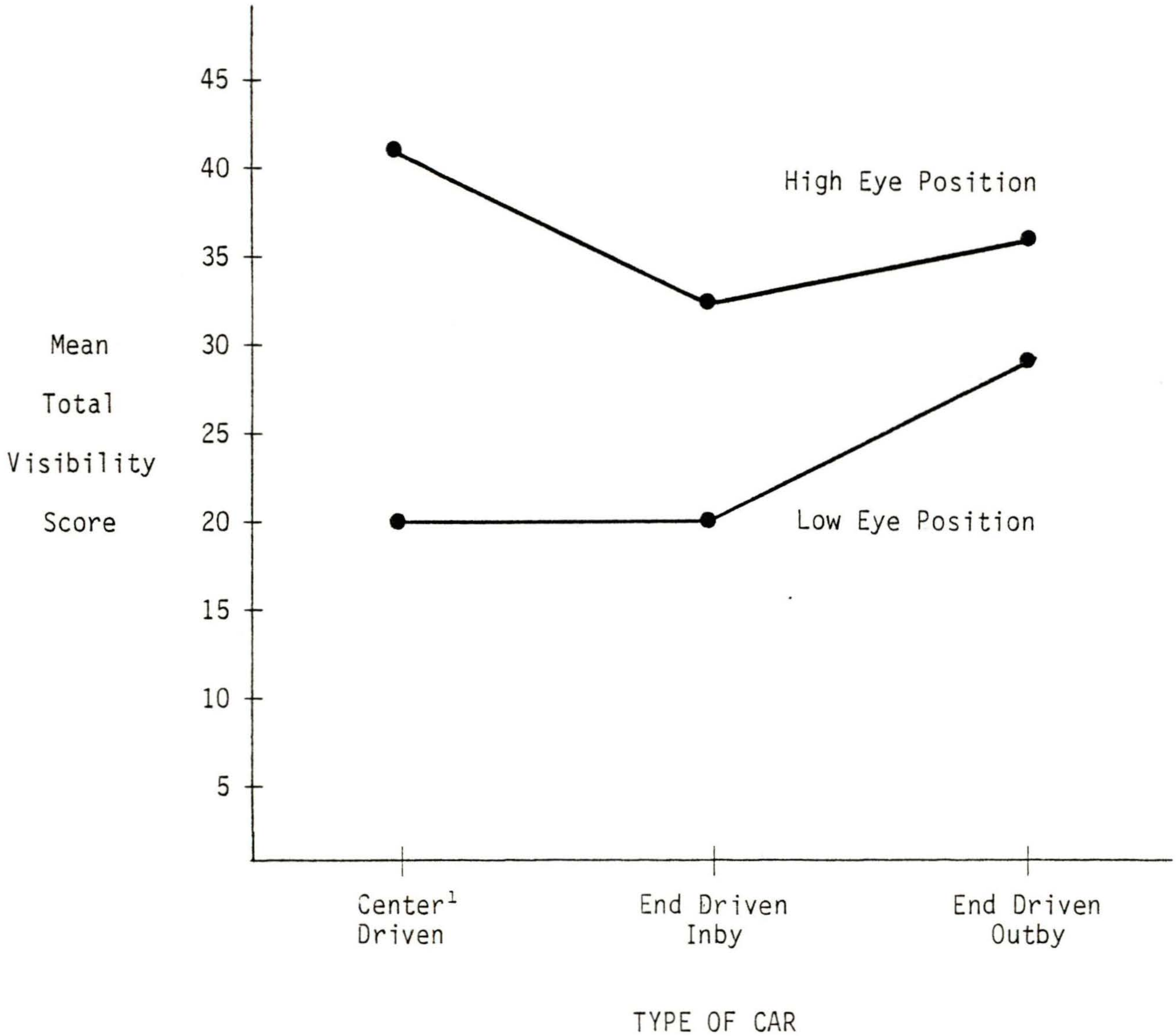
2.2.3 <u>End driven versus center driven cars</u>. To compare end driven cars with center driven cars, the data were divided with respect to HERMI eye position and direction of travel. The following sample sizes were used to make the comparisons:

	Center Driven	End Driven
Inby		
Low Eye	4	6
High Eye	5	2
Outby		
Low Eye	4	5
High Eye	5	3

The mean total visibility for center driven and end driven cars in the inby and outby direction of travel is shown in Figure 2.2. High and low HERMI eye positions are presented separately. The data show a definite effect of this variable which will be discussed further in Section 2.2.6.

With HERMI in the low canopy posture, there is a statistically reliable difference ($t = 2.75$, $df = 7$, $p < .05$) between visibility from center driven cars and that from end driven cars in the outby direction. As would be expected, visibility was better with end driven cars, since in the outby direction, the cab is at the front of an end driven car, but in the middle of a center driven car. There was, however, no difference in visibility between the center driven cars and the end driven cars in the inby direction ($t = 0.0$).

It appears, then, that with HERMI in the low canopy position, visibility is improved by placing the cab in the front of the car as compared to the center or rear of the car. However, placing the cab in center does not appear to add additional visibility over that obtained with the cab in the rear.



[1]Inby and outby visibility is considered equal for center driven cars.

Figure 2.2. Mean total visibility for center and end driven cars.

With HERMI in the high canopy position, however, there are no reliable differences in total visibility between center driven cars and end driven cars in either the inby ($t = 0.84$, $df = 5$, $p>.05$) or outby ($t = 0.66$, $df = 6$, $p>.05$) directions of travel. It appears that with the improved eye position, i.e., sitting higher in the cab, it does not make much difference where the cab is positioned, i.e., front, center, or rear. Only when the eye position is low, is visibility better with the cab in front than at the center or rear.

2.2.4 Inby versus outby direction of travel. To compare the two directions of travel, only end driven cars were used. Each car supplied data from both directions of travel, HERMI eye positions were the same in both measurements. A total of eight inby and eight outby measurements were made on the three end driven cars. As would be expected, total visibility was higher in the outby direction (mean = 32.2) than in the inby direction (mean = 24.5). The difference was statistically reliable ($t = 5.8$, $df = 7$, $p<.01$). Converting the visibility score to a percentage of the 54 VALs, 60 percent of the VALs are visible in the outby direction, while only 45 percent are visible in the inby direction.

2.2.5 Seam height. To compare high and low seam cars, the data were divided by direction of travel and HERMI eye position. Figure 2.3 shows the mean total visibility scores for the various combinations. In the inby direction of travel, there is virtually no difference between high and low seam cars with HERMI in either eye position. (The small difference with the high eye position is not statistically reliable.) In the outby direction, with HERMI in the low eye position, there is a trend for visibility to be better in the high seam cars, however, this difference was not statistically reliable ($t = 2.13$, $df = 8$, $p>.05$). Part of this difference is due to the fact that two of three high seam cars are end driven with the operator in front in the outby direction, whereas, two of the three low seam cars are center driven with the operator in the middle in the outby direction. We must conclude, therefore, that the differences between high and low seam cars in the outby direction are not due to the overall size of the car, but rather to the placement of the cab.

2.2.6 HERMI eye position. To test the effect of HERMI eye position, matched pairs of measurements were found wherein one member of the pair had HERMI in the high position and the other member had HERMI in the low position. The members of the pair were from the same machine, in the same direction of travel. Five pairs in the inby and five pairs in the outby direction were found. Figure 2.4 presents the mean total visibility scores. In both the inby and outby directions of travel, the high eye position resulted in reliably better visibility than with the low eye position ($t = 2.80$, $df = 8$, $p<.05$; $t = 2.60$, $df = 8$, $p<.05$, for inby and outby directions respectively).

Combining the inby and outby directions of travel, the mean visibility in the high eye position is 38.0 and in the low eye position 23.7. Converting these scores into percentages, we find that on the average approximately three-quarters (71 percent) of the VALs are visible in the high eye position compared to only about half (44 percent) in the low eye position.

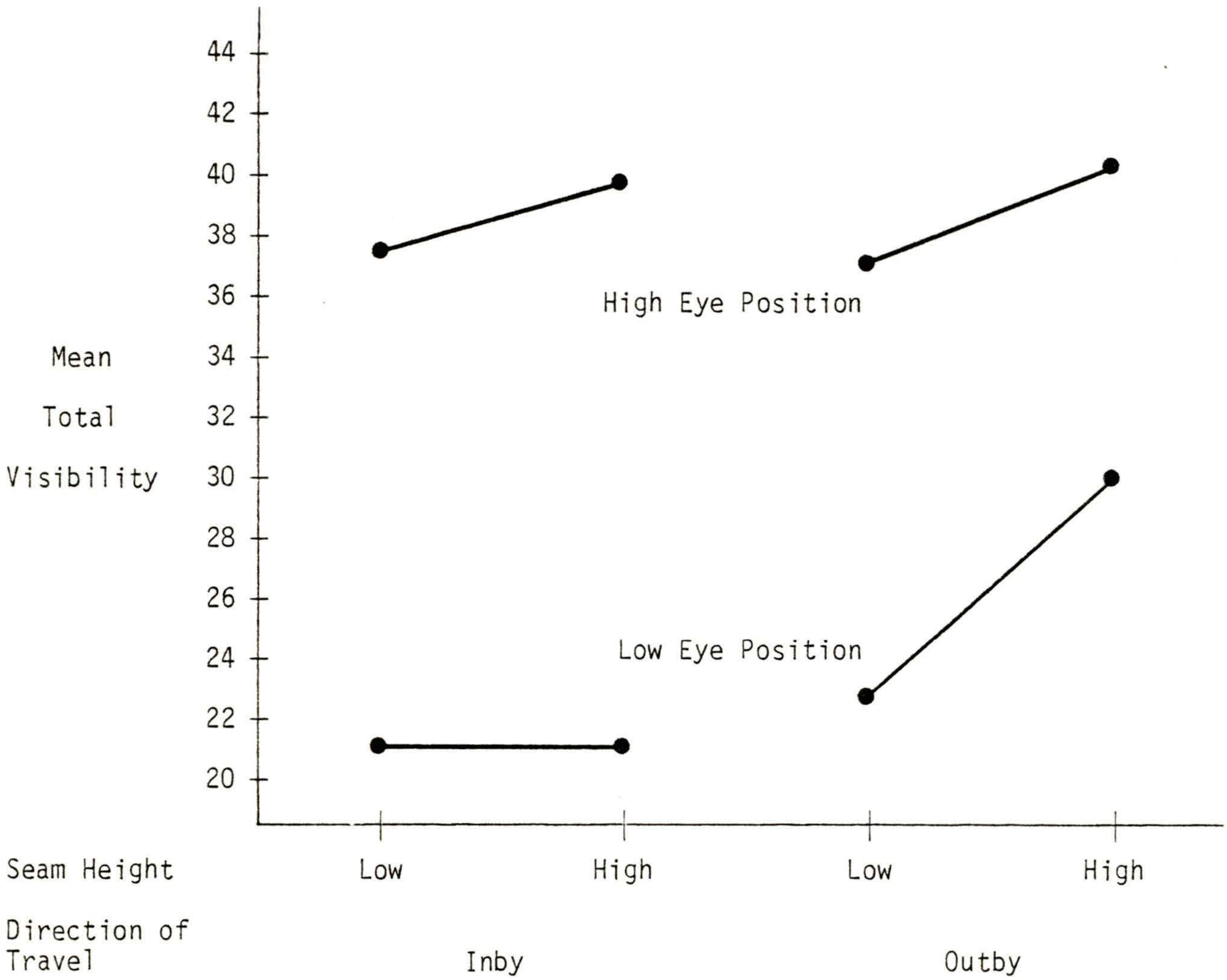


Figure 2.3. Comparison of high and low seam machines in terms of total visibility scores.

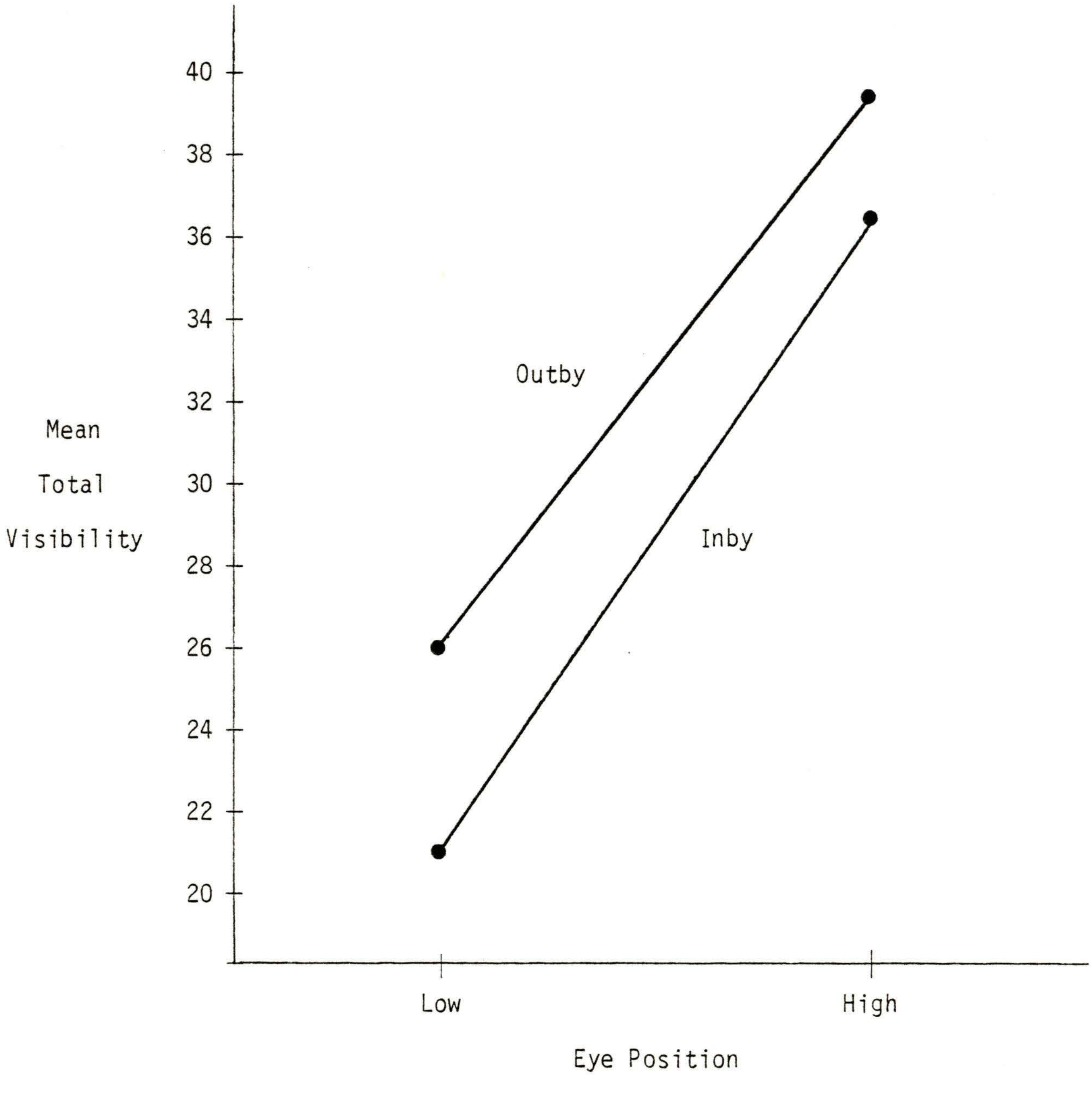


Figure 2.4. Comparison of high and low HERMI eye position.

2.2.7 Canopy. This variable is of particular importance to this study and is discussed last so that the effect of the other variables could be appreciated before exploring the effect of canopy. As shown above, eye position is an important variable for visibility. Canopy height determines, in part, eye position. Thus, insofar as lowering canopy height lowers eye position, visibility will be degraded. With high seam machines, even the lowest canopy height may not impinge on the operator, in which case visibility could be the same as if the canopy were in the highest position.

The question of interest, however, is whether the canopy, per se, affects visibility. That is if the eye position is not changed, will adding a canopy degrade visibility? To answer this question, comparisons were made between canopy and no canopy conditions in which the eye position of HERMI was the same.

With HERMI in the low eye position, six canopy-no canopy matched pairs (matched on machine and direction of travel) could be found. There was virtually no difference in mean total visibility between the canopy and no canopy conditions (23.5 and 24 respectively). With HERMI in the high eye positon, only three matched pairs could be found. The mean for the no canopy condition was 39.3 and the mean for the canopy condition was 42.0; this small difference is not reliable ($t = 1.36$, $df = 2$, $p>.10$).

From this data, we must conclude that as far as VAL visibility is concerned, a canopy, per se, does not degrade visibility unless it requires the operator to assume a lower eye position with the canopy than without.

2.2.8 Visibility at individual VALs. It has been assumed that visibility would be the same in the inby and outby direction for center driven cars. Therefore, the outby data from center driven cars was also included in the inby data set. The previously discussed results showed that the principle variable affecting visibility was eye height, therefore, results will be presented separately for the high and low eye positions. Table 2.3 presents the percentage of cases in which each VAL was visible for center driven cars. The data for the inby and outby directions of travel are the same. Table 2.4 is analogous to Table 2.3, but presents data from end driven cars. Unfortunately, the sample size with HERMI in the high position is very small for end driven cars.

Tables 2.3 and 2.4 reinforce the results presented previously, that is, visibility is better with HERMI in the "high canopy" eye position than in the low position. For end driven cars, visibility is better in the outby direction of travel (cab in the front) than in the inby direction (cab in the rear), but the differences are smaller in the cases where HERMI is in the high position then when in the low position.

Other trends can be noted in Tables 2.3 and 2.4. Visibility is better for VALs on the same side of the machine as the operator (i.e., SS) than for those on the opposite side (i.e., OS). The higher the VAL in vertical space, generally, the greater the proportion of cases in which it can be seen. The differences are greatest between floor VALs and other VALs, than between VALs above floor level, at a given location (fore-aft, side-to-side).

Table 2.3. Percentage of Cases in which VAL is Visible for Center Driven Cars

	NO.	FORE-AFT	SIDE-TO-SIDE	UP-DOWN	INBY[1] (4)[2] LOW[3]	INBY[1] (5) HIGH[3]	OUTBY[1] (4) L	OUTBY[1] (5) H
A	1	RE	MCL	OEH	0	60	0	60
	2	RE	MCL	HMP	0	80	0	80
B	3	OH	MCL	OEH	25	100	25	100
	4	OH	MCL	HMP	25	100	25	100
C	5	OH + 1/2 NSD	WMP(SS) + 3'	OEH	100	100	100	100
D	6	FE + 2'	WMP(SS) + 1/2 NSD	Floor	100	100	100	100
	7	FE + 2'	WMP(SS) + 1/2 NSD	HMP	100	100	100	100
E	8	FE + 2'	WMP(SS) + 3'	Floor	100	100	100	100
	9	FE + 2'	WMP(SS) + 3'	MMH	100	100	100	100
	10	FE + 2'	WMP(SS) + 3'	OEH	100	100	100	100
	11	FE + 2'	WMP(SS) + 3'	HMP	100	100	100	100
F	12	FE	MCL	MMH	0	80	0	80
	13	FE	MCL	OEH	0	80	0	80
	14	FE	MCL	HMP	25	100	25	100
	15	FE	MCL	SH or MBH	100	100	100	100
G	16	FE + 2'	WMP(OS) + 2'	Floor	0	0	0	0
	17	FE + 2'	WMP(OS) + 2'	MMH	0	40	0	40
	18	FE + 2'	WMP(OS) + 2'	HMP	25	80	25	80
H	19	FE + 2'	WMP(OS) + 1/2 NSD	Floor	0	0	0	0
	20	FE + 2'	WMP(OS) + 1/2 NSD	MMH	0	40	0	40
	21	FE + 2'	WMP(OS) + 1/2 NSD	OEH	0	80	0	80
	22	FE + 2'	WMP(OS) + 1/2 NSD	HMP	0	80	0	80
I	23	FE + 1/2 NSD	WMP(OS) + 1/2 NSD	Floor	0	0	0	0
	24	FE + 1/2 NSD	WMP(OS) + 1/2 NSD	OEH	0	80	0	80
	25	FE + 1/2 NSD	WMP(OS) + 1/2 NSD	HMP	25	100	25	100
J	26	FE + 1/2 NSD	WMP(OS) + 2'	Floor	0	0	0	0
	27	FE + 1/2 NSD	WMP(OS) + 2'	HMP	0	100	0	100
K	28	FE + 1/2 NSD	MCL	MMH	0	80	0	80
	29	FE + 1/2 NSD	MCL	SH	100	100	100	100
L	30	FE + 1/2 NSD	OCL	Floor	25	40	25	40
	31	FE + 1/2 NSD	OCL	SH	75	100	75	100
M	32	FE + 1/2 NSD	WMP(SS) + 3'	Floor	100	100	100	100
	33	FE + 1/2 NSD	WMP(SS) + 3'	MMH	100	100	100	100
	34	FE + 1/2 NSD	WMP(SS) + 3'	HMP	100	100	100	100
N	35	FE + 1/2 NSD	WMP(SS) + 1/2 NSD	Floor	100	100	100	100
	36	FE + 1/2 NSD	WMP(SS) + 1/2 NSD	HMP	100	100	100	100
O	37	FE + NSD	WMP(SS) + 1/2 NSD	Floor	100	100	100	100
	38	FE + NSD	WMP(SS) + 1/2 NSD	OEH	100	100	100	100
	39	FE + NSD	WMP(SS) + 1/2 NSD	HMP	100	100	100	100
P	40	FE + NSD	WMP(SS) + 2'	Floor	50	80	50	80
	41	FE + NSD	WMP(SS) + 2'	OEH	50	80	50	80
	42	FE + NSD	WMP(SS) + 2'	HMP	50	100	50	100
Q	43	FE + NSD	OCL	MMH	25	60	25	60
	44	FE + NSD	OCL	HMP	25	100	25	100
R	45	FE + NSD	MCL	Floor	0	0	0	0
	46	FE + NSD	MCL	MMH	0	60	0	60
	47	FE + NSD	MCL	OEH	0	80	0	80
	48	FE + NSD	MCL	HMP	0	100	0	100
S	49	FE + NSD	WMP(OS)	Floor	0	20	0	20
	50	FE + NSD	WMP(OS)	OEH	0	80	0	80
	51	FE + NSD	WMP(OS)	HMP	0	80	0	80
T	52	FE + NSD	WMP(OS) + 1/2 NSD	Floor	0	0	0	0
	53	FE + NSD	WMP(OS) + 1/2 NSD	OEH	0	80	0	80
	54	FE + NSD	WMP(OS) + 1/2 NSD	HMP	0	80	0	80

[1] Direction of travel.

[2] Sample size, number of cases.

[3] HERMI eye position.

Table 2.4. Percentage of Cases in which VAL is Visible for End Driven Cars

	NO.	FORE-AFT	SIDE-TO-SIDE	UP-DOWN	INBY[1] (6)[2] LOW[3]	INBY[1] (2) HIGH[3]	OUTBY[1] (5) LOW	OUTBY[1] (3) HIGH
A	1	RE	MCL	OEH	0	100	0	33
	2	RE	MCL	HMP	33	100	0	33
B	3	OH	MCL	OEH	0	100	0	67
	4	OH	MCL	HMP	33	100	40	67
C	5	OH + 1/2 NSD	WMP(SS) + 3'	OEH	100	100	100	100
D	6	FE + 2'	WMP(SS) + 1/2 NSD	Floor	100	100	100	100
	7	FE + 2'	WMP(SS) + 1/2 NSD	HMP	100	100	100	100
E	8	FE + 2'	WMP(SS) + 3'	Floor	100	100	100	100
	9	FE + 2'	WMP(SS) + 3'	MMH	100	100	100	100
	10	FE + 2'	WMP(SS) + 3'	OEH	100	100	100	100
	11	FE + 2'	WMP(SS) + 3'	HMP	100	100	100	100
F	12	FE	MCL	MMH	0	50	0	33
	13	FE	MCL	OEH	0	50	0	67
	14	FE	MCL	HMP	33	50	40	67
	15	FE	MCL	SH or MBH	67	50	80	67
G	16	FE + 2'	WMP(OS) + 2'	Floor	0	0	0	0
	17	FE + 2'	WMP(OS) + 2'	MMH	0	50	0	33
	18	FE + 2'	WMP(OS) + 2'	HMP	0	50	20	67
H	19	FE + 2'	WMP(OS) + 1/2 NSD	Floor	0	0	0	0
	20	FE + 2'	WMP(OS) + 1/2 NSD	MMH	0	50	0	33
	21	FE + 2'	WMP(OS) + 1/2 NSD	OEH	0	50	0	33
	22	FE + 2'	WMP(OS) + 1/2 NSD	HMP	0	50	0	33
I	23	FE + 1/2 NSD	WMP(OS) + 1/2 NSD	Floor	0	0	0	0
	24	FE + 1/2 NSD	WMP(OS) + 1/2 NSD	OEH	0	0	0	33
	25	FE + 1/2 NSD	WMP(OS) + 1/2 NSD	HMP	0	50	0	33
J	26	FE + 1/2 NSD	WMP(OS) + 2'	Floor	0	0	0	0
	27	FE + 1/2 NSD	WMP(OS) + 2'	HMP	0	50	40	33
K	28	FE + 1/2 NSD	MCL	MMH	0	50	60	100
	29	FE + 1/2 NSD	MCL	SH	67	50	100	100
L	30	FE + 1/2 NSD	OCL	Floor	0	0	80	100
	31	FE + 1/2 NSD	OCL	SH	83	50	100	100
M	32	FE + 1/2 NSD	WMP(SS) + 3'	Floor	67	100	100	100
	33	FE + 1/2 NSD	WMP(SS) + 3'	MMH	100	100	100	100
	34	FE + 1/2 NSD	WMP(SS) + 3'	HMP	100	100	100	100
N	35	FE + 1/2 NSD	WMP(SS) + 1/2 NSD	Floor	100	100	100	100
	36	FE + 1/2 NSD	WMP(SS) + 1/2 NSD	HMP	100	100	100	100
O	37	FE + NSD	WMP(SS) + 1/2 NSD	Floor	100	100	100	100
	38	FE + NSD	WMP(SS) + 1/2 NSD	OEH	100	100	100	100
	39	FE + NSD	WMP(SS) + 1/2 NSD	HMP	100	100	100	100
P	40	FE + NSD	WMP(SS) + 2'	Floor	83	50	100	100
	41	FE + NSD	WMP(SS) + 2'	OEH	83	100	100	100
	42	FE + NSD	WMP(SS) + 2'	HMP	83	100	100	100
Q	43	FE + NSD	OCL	MMH	67	100	67	100
	44	FE + NSD	OCL	HMP	67	100	100	100
R	45	FE + NSD	MCL	Floor	0	0	60	100
	46	FE + NSD	MCL	MMH	0	50	100	100
	47	FE + NSD	MCL	OEH	0	50	100	100
	48	FE + NSD	MCL	HMP	0	50	100	100
S	49	FE + NSD	WMP(OS)	Floor	0	0	0	0
	50	FE + NSD	WMP(OS)	OEH	0	50	40	33
	51	FE + NSD	WMP(OS)	HMP	0	50	40	33
T	52	FE + NSD	WMP(OS) + 1/2 NSD	Floor	0	0	0	0
	53	FE + NSD	WMP(OS) + 1/2 NSD	OEH	0	0	0	33
	54	FE + NSD	WMP(OS) + 1/2 NSD	HMP	0	50	0	33

[1]Direction of travel.

[2]Sample size, number of cases.

[3]HERMI eye position.

Although with a little effort, one can gain an overall picture of the field of visibility by examining Tables 2.3 and 2.4, it was deemed desirable to present the data in a more pictorial format. To do that requires some combining of data in order to reduce the three-dimensional VAL space to two-dimensional paper and preserve the effect of type of car (end versus center) and HERMI eye position. Figures 2.5, 2.6, 2.7, and 2.8 present the data for center driven cars. Since the greatest differences occur between the floor VALs and other VALs, floor VALs are presented separately in Figures 2.5 and 2.6. Figure 2.5 presents data with HERMI in the low eye position, and Figure 2.6 presents data with HERMI in the high position. A comparison of Figures 2.5 and 2.6 shows the improvement in visibility from raising the eye position. Figures 2.7 and 2.8 present low and high eye position data combining all VALs above floor level at each position. The mean percentages are used. Figures 2.9, 2.10, 2.11, and 2.12 present the data for end driven cars in the same manner as the previous four figures.

With both end and center driven cars, the effect of eye position is very slight with respect to floor VALs. Eye position, however, does affect visibility of VALs located above floor level. In general, for both end and center driven cars, raising the eye position increases visibility of VALs on the opposite side of the machine from the operator's cab and VALs at the necessary stopping distance. The differences between high and low eye positions for VALs above floor level are greatest for center driven cars. For end driven cars, the differences are greatest in the inby direction of travel.

Considering all the data, only five VALs were not visible from any car in any direction with HERMI in either the high or low eye positions. The five VALs are:

Location	Number	Fore-Aft	Side-to-Side	Up-Down
G	16	FE + 2'	WMP (OS) + 2'	Floor
H	19	FE + 2'	WMP (OS) + 1/2 NSD	Floor
I	23	FE + 1/2 NSD	WMP (OS) + 1/2 NSD	Floor
J	26	FE + 1/2 NSD	WMP (OS) + 2'	Floor
T	52	FE + NSD	WMP (OS) + 1/2 NSD	Floor

In addition, the following VAL should be added to the list of five. In only one case was it visible (center driven high eye position), and its position is congruent with the other five.

Location	Number	Fore-Aft	Side-to-Side	Up-Down
S	49	FE + NSD	WMP (OS)	Floor

These six VALs are all located at floor level, on the opposite side of the machine from the operator's cab and from two feet to the necessary stopping distance in front of the machine. Based on this data, it appears that, that area is probably not visible from any shuttle car being manufactured today. This will be discussed further in Section 4.0 of this report.

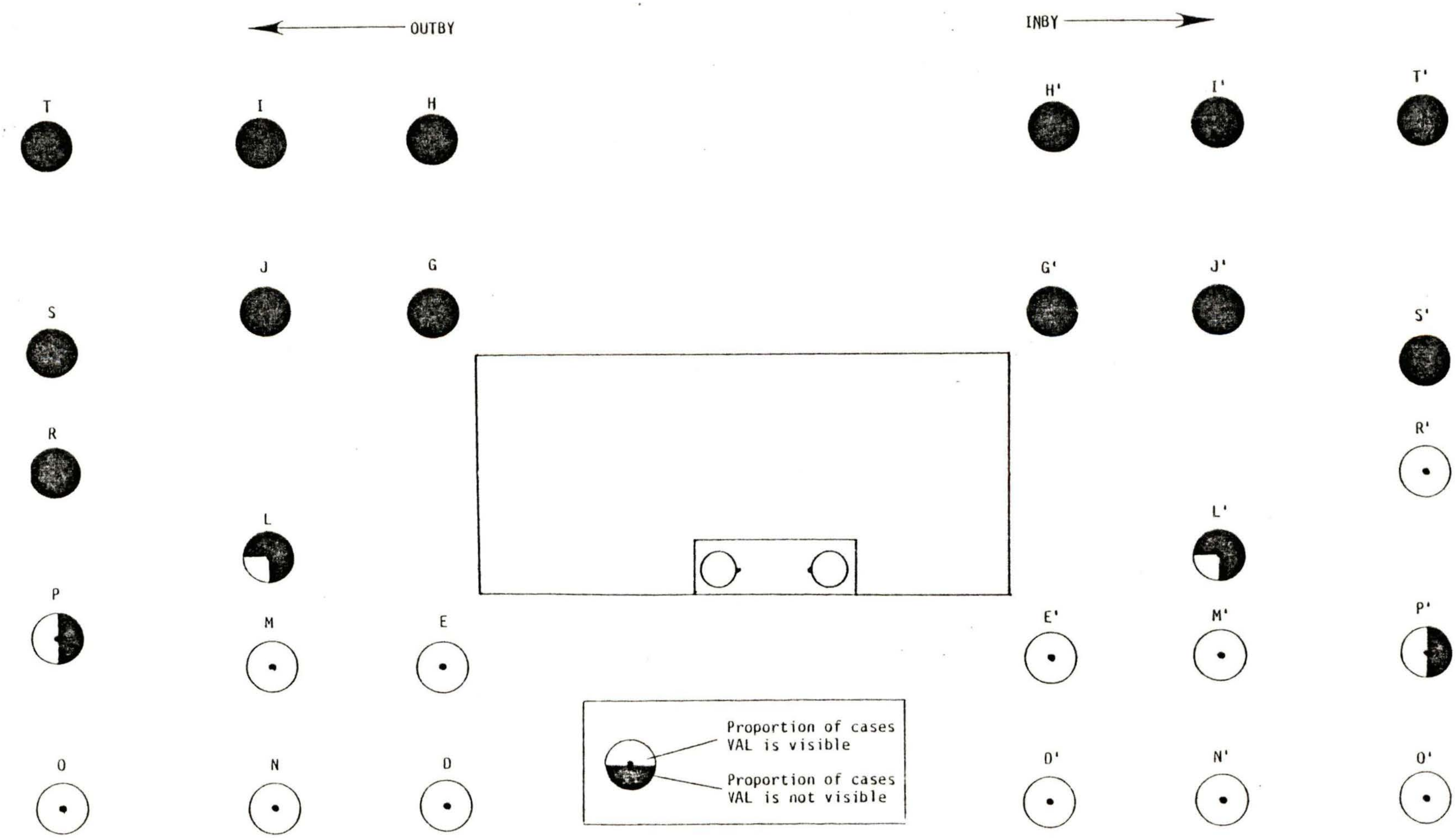


Figure 2.5. Center driven cars: Proportion of cases in which VAL is visible; floor VALs only, HERMI in low eye position.

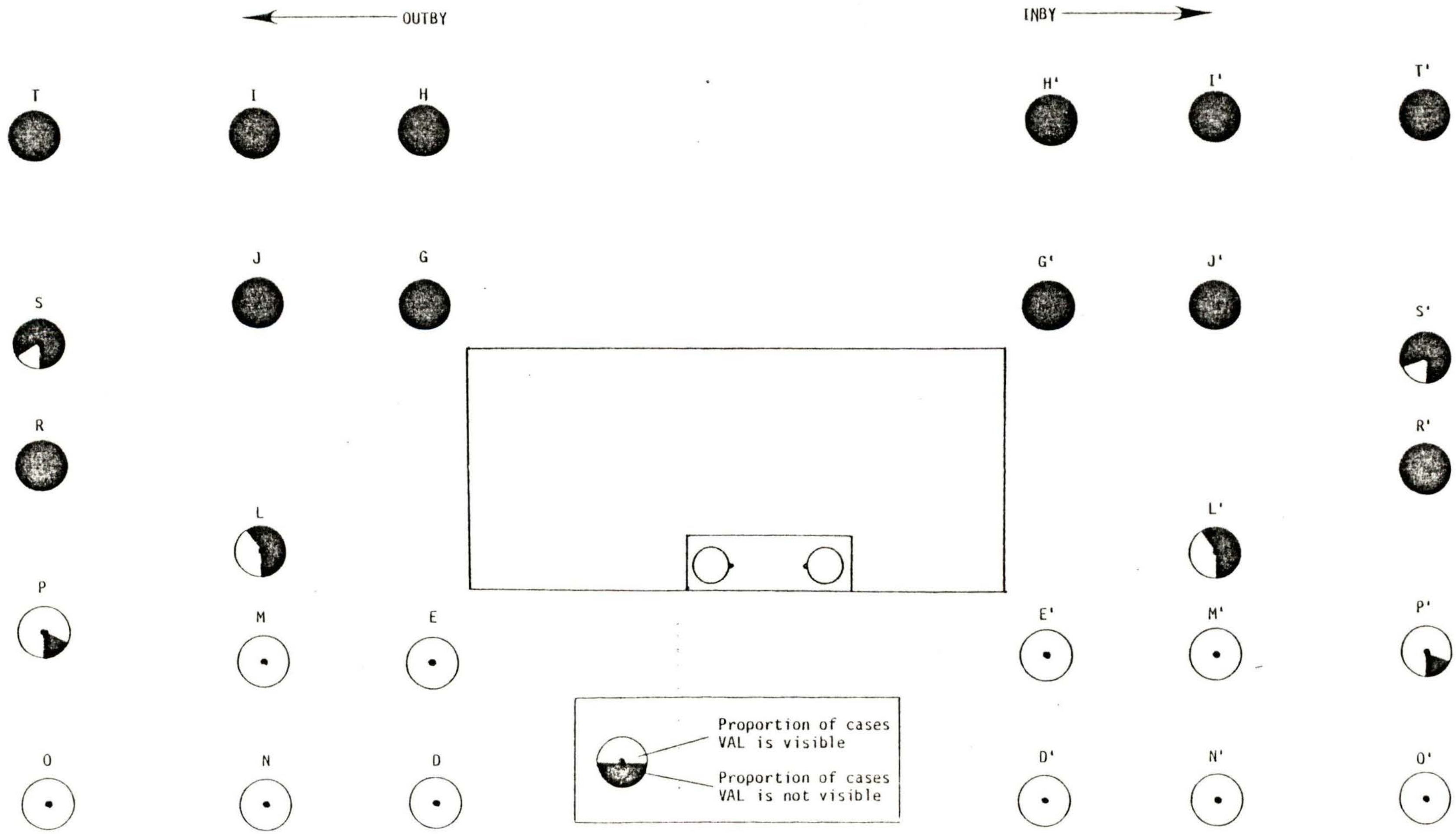


Figure 2.6. Center driven cars: Proportion of cases in which VAL is visible; floor VALs only, HERMI in <u>high</u> eye position.

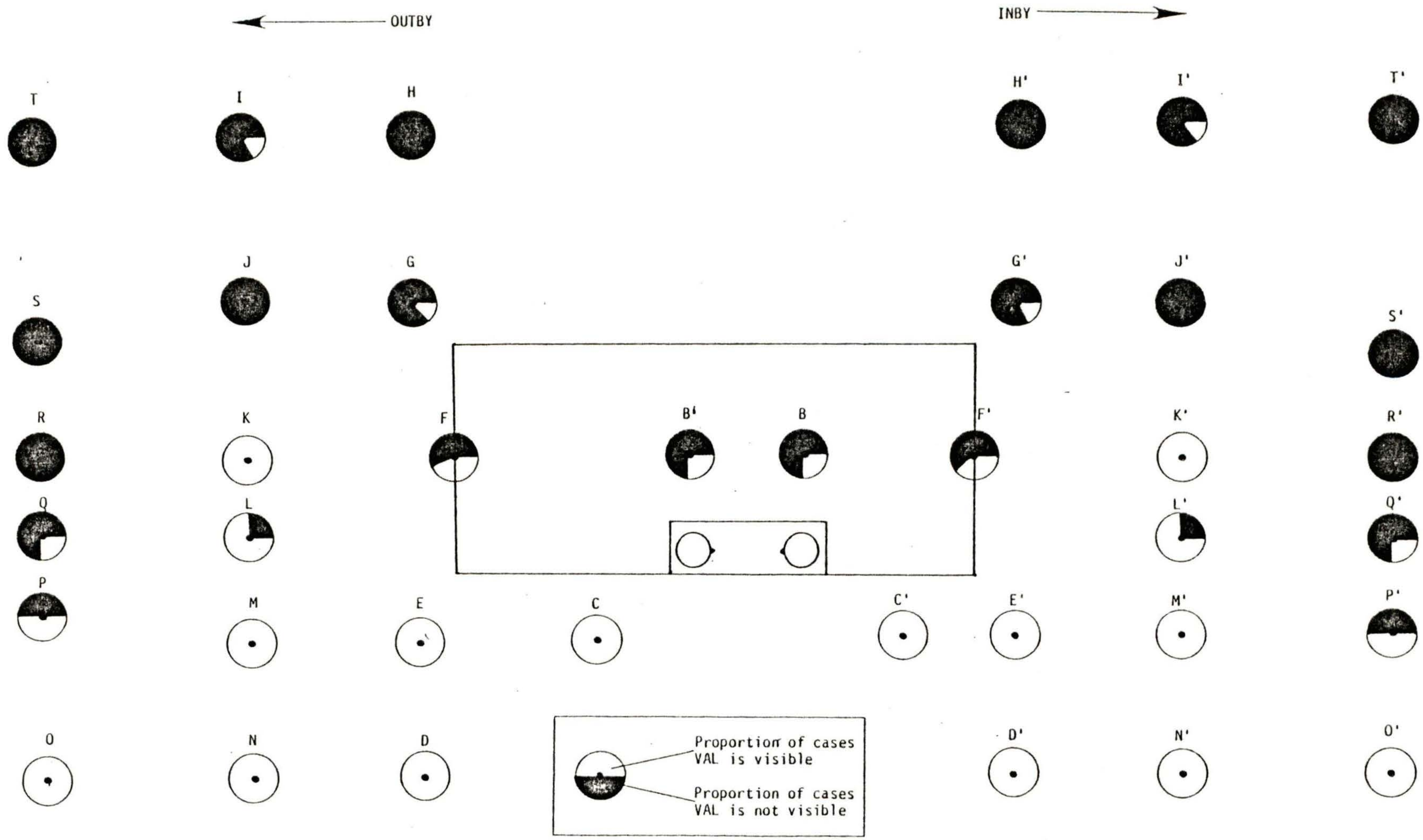


Figure 2.7. Center driven cars: Proportion of cases in which VAL is visible; mean of all VALs above floor level at each location, HERMI in <u>low</u> eye position.

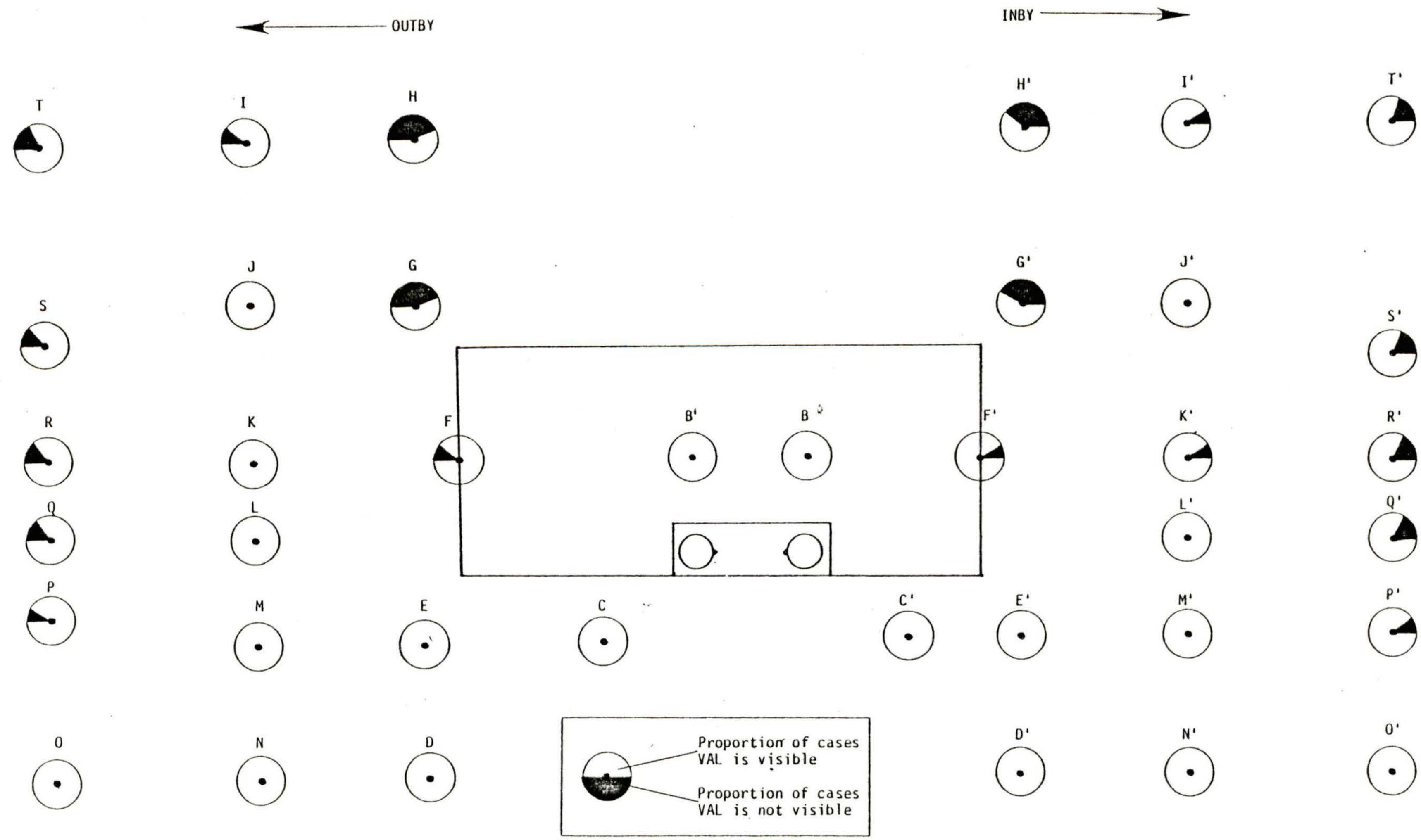


Figure 2.8. Center driven cars: Proportion of cases in which VAL is visible; mean of all VALs above floor level at each location, HERMI in <u>high</u> eye position.

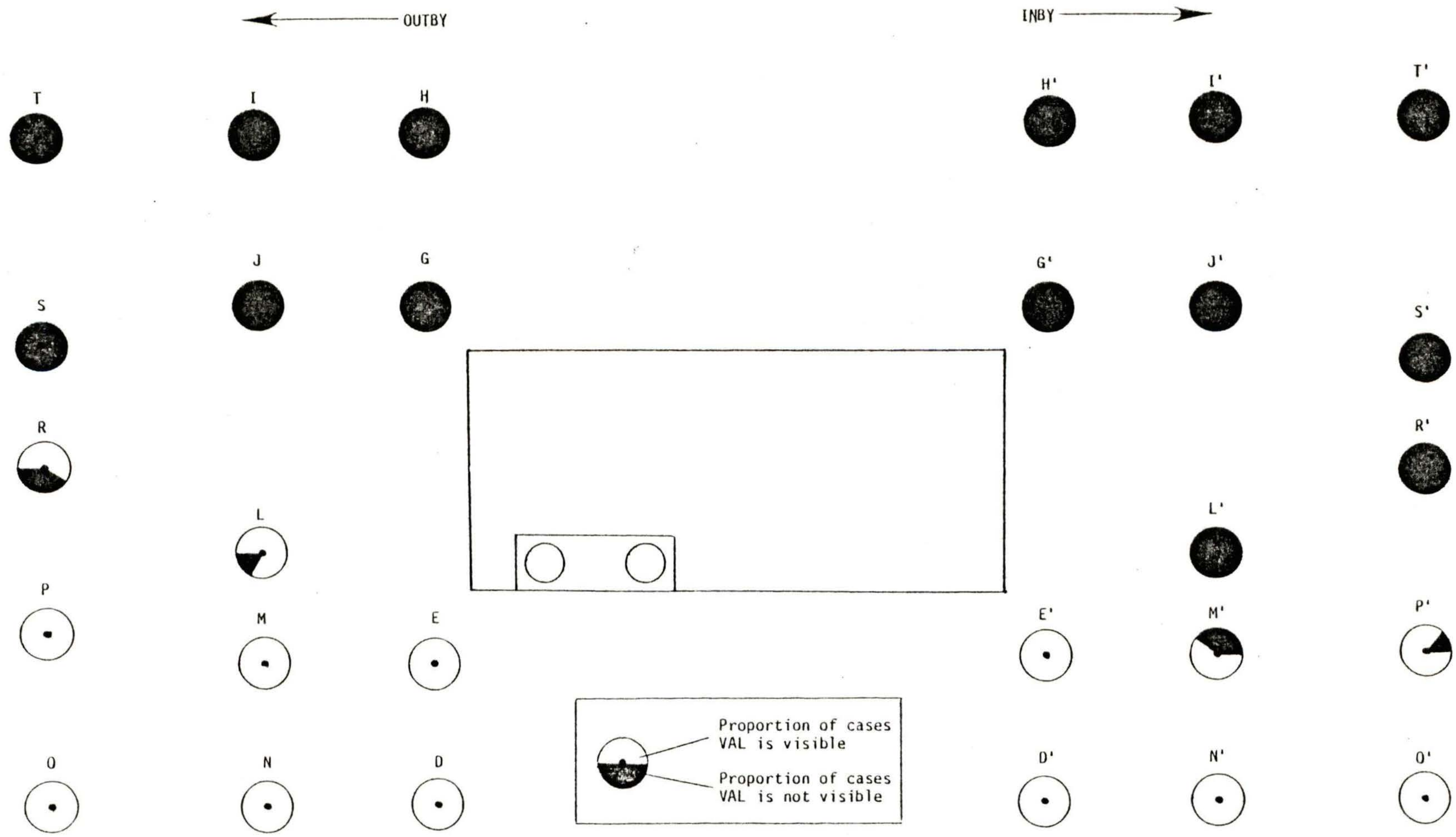


Figure 2.9. End driven car: Proportion of cases in which VAL is visible; floor VALs only, HERMI in low eye position.

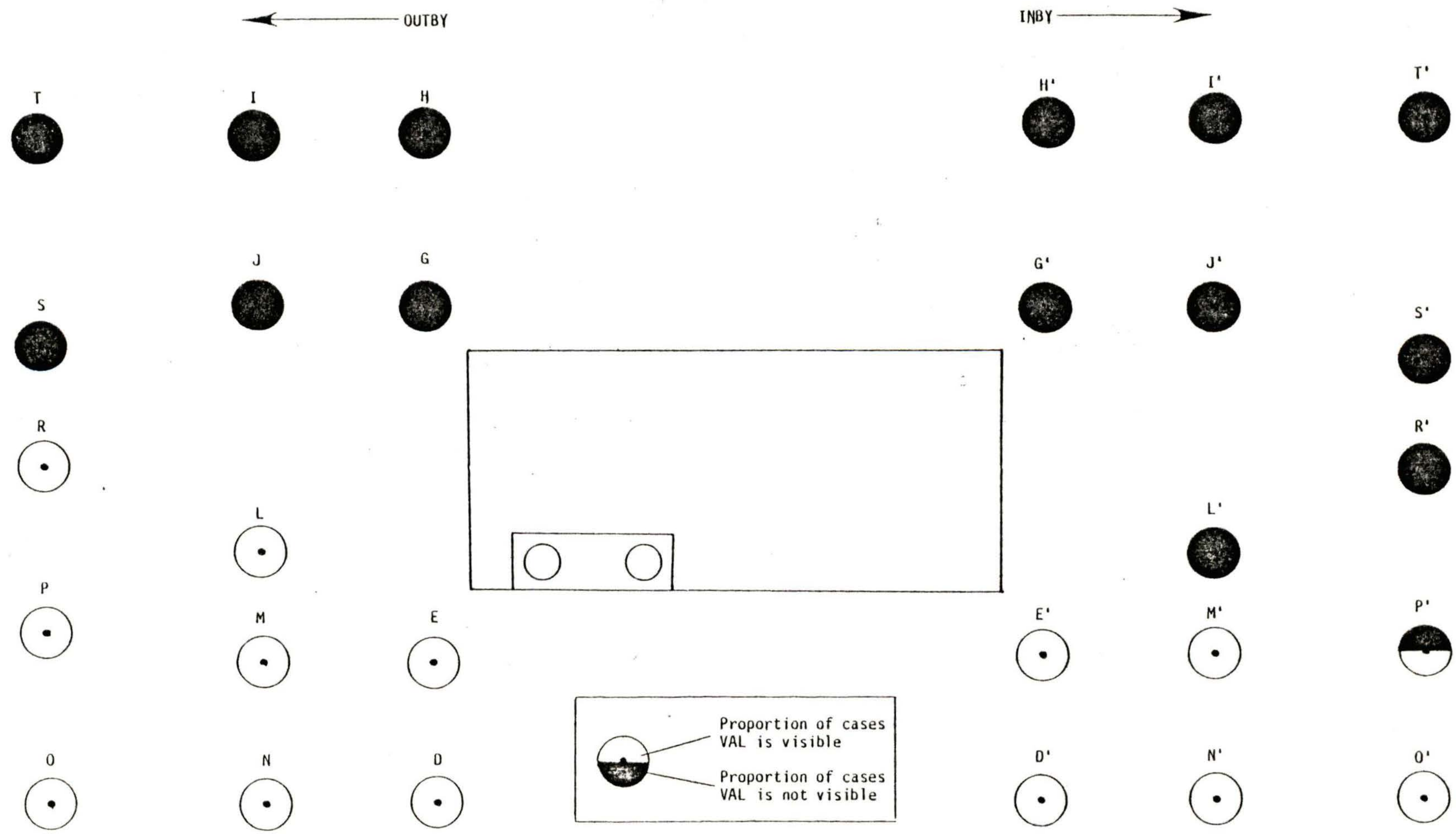


Figure 2.10. End driven cars: Proportion of cases in which VAL is visible; floor VALs only, HERMI in <u>high</u> eye position.

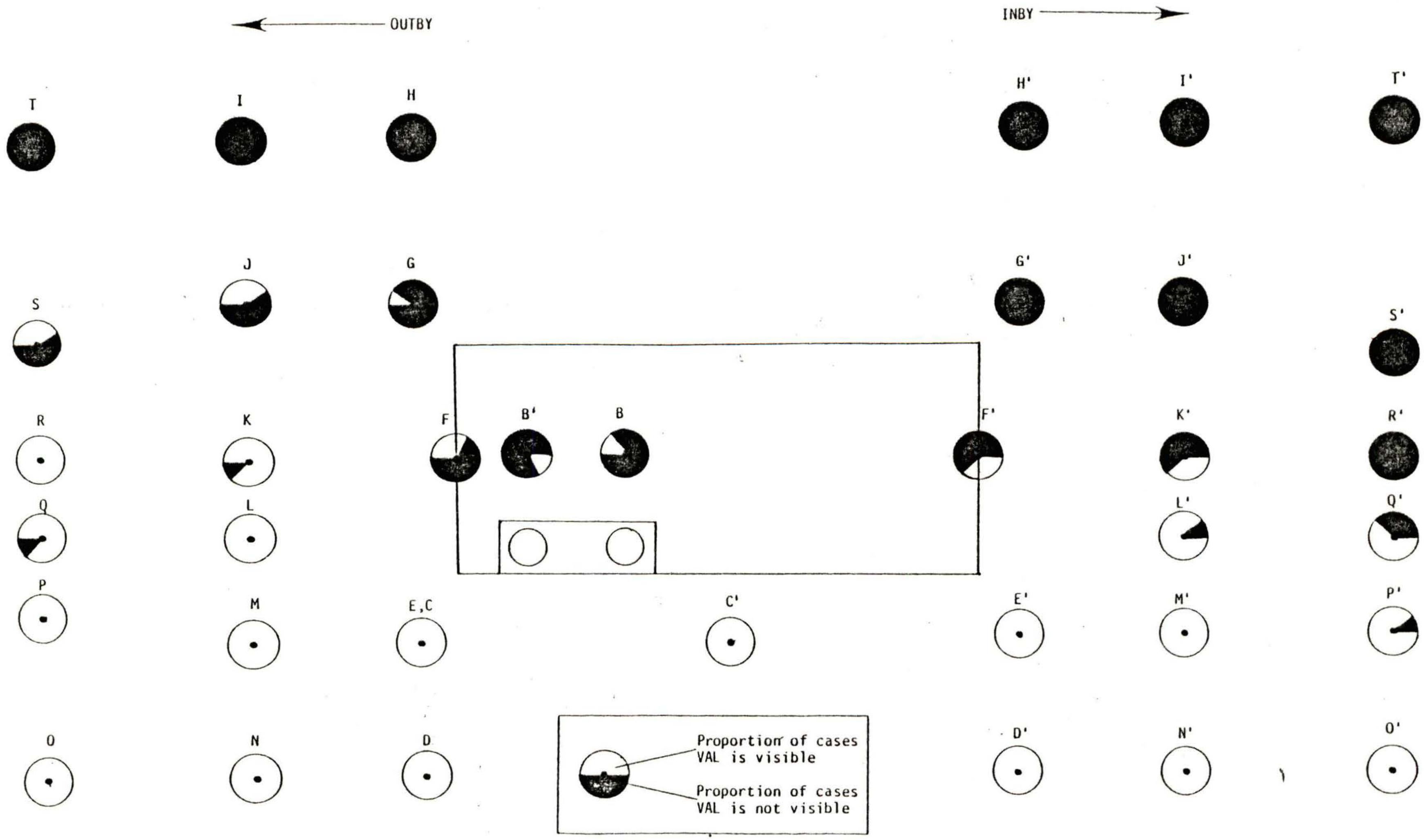


Figure 2.11. End driven cars: Proportion of cases in which VAL is visible; mean of all VALs above floor level at each location, HERMI in low eye position.

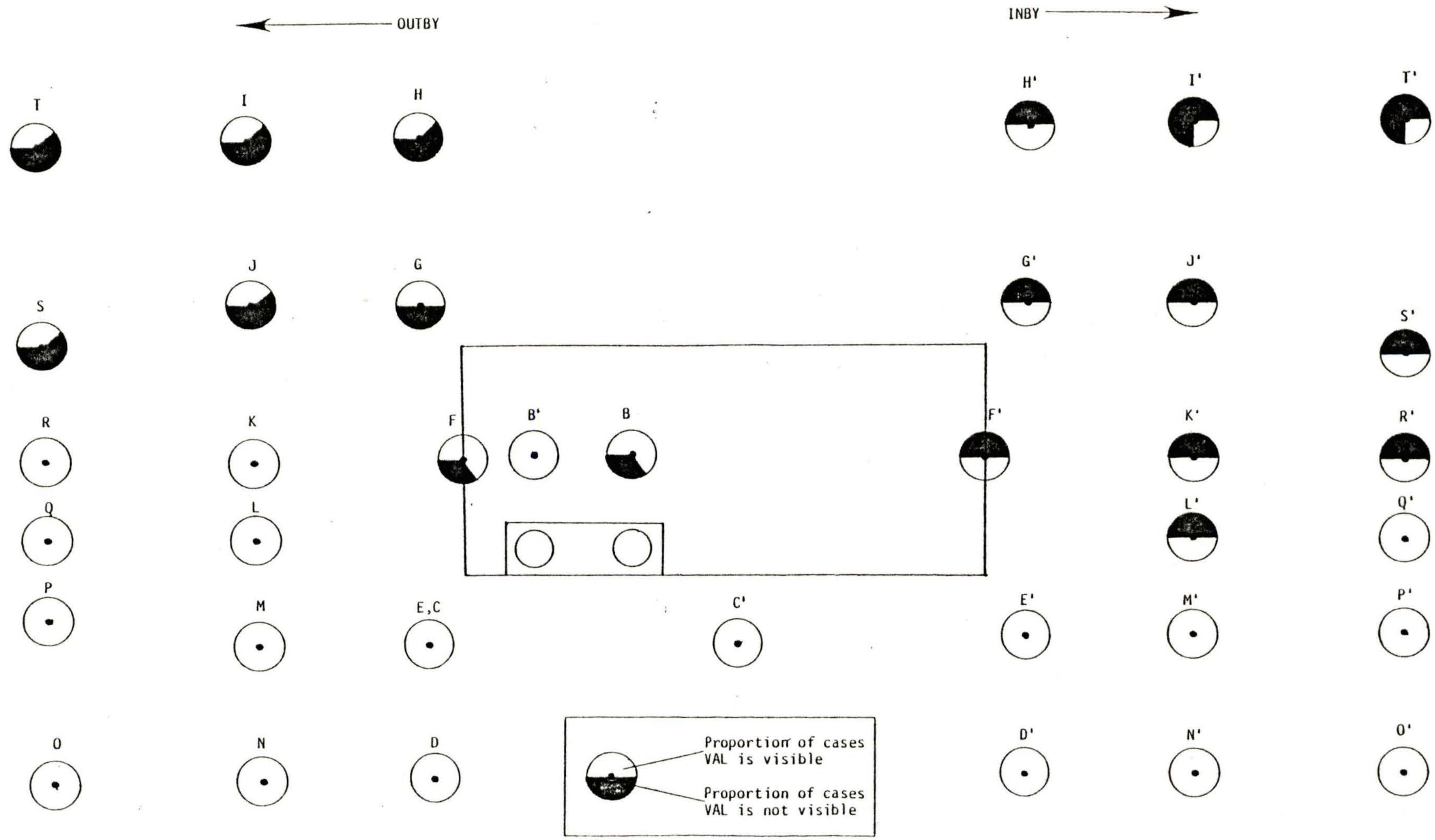


Figure 2.12. End driven cars: Proportion of cases in which VAL is visible; mean of all VALs above floor level at each location, HERMI in high eye position.

2.3 Conclusions

From an analysis of the visibility data, the following conclusions can be made with a good deal of confidence:

1. The addition of a canopy, per se, does not degrade visibility, insofar as it does not require operators to lower their eye position.

2. The higher the operator's eye position, the better is visibility. The improvement comes principally from being better able to see VALs above floor level, and on the opposite side of the machine.

3. The overall height of the machine (high seam versus low seam) does not affect visibility, insofar as the operator's eye position remains the same. This is to say that visibility in a low seam car with the canopy in its lowest position is equal to visibility in a high seam car with its canopy in the lowest position.

4. For end driven cars, visibility is better in the outby direction (cab in front) than in the inby direction (cab in rear).

5. Comparisons between end and center driven cars must take into account eye position and direction of travel. With high eye position, visibility is essentially the same for end and center cars. With a low eye position, however, end cars have better visibility than center driven cars in the outby direction, but there is no difference in the inby direction.

6. Blind areas exist for virtually all shuttle cars at floor level, on the opposite side of the car from the operator's compartment, and ahead of the machine. These blind areas exist in both directions of travel, for both end and center driven cars, and with eyes in both high and low positions.

3.0 ILLUMINATION LEVELS AT VALS

3.1 Method

3.1.1 Shuttle car sample. A total of six shuttle cars were used as the sample. The sample is the same as discussed in Section 2.0 of this report. To summarize, cars from three manufacturers were sampled, three of the cars were designed for low seam operations (i.e. less than 48 inches) and three for high seam operations (i.e. greater than 48 inches). Of the low seam cars, two were center driven and one was end driven. Of the high seam cars, two were end driven and one was center driven.

3.1.2 Illumination measurement apparatus. The illumination levels were measured with a Lite Mate/Spot Mate Photometer System (Photo Research, Burbank, CA). The device was calibrated both before and after the field tests.

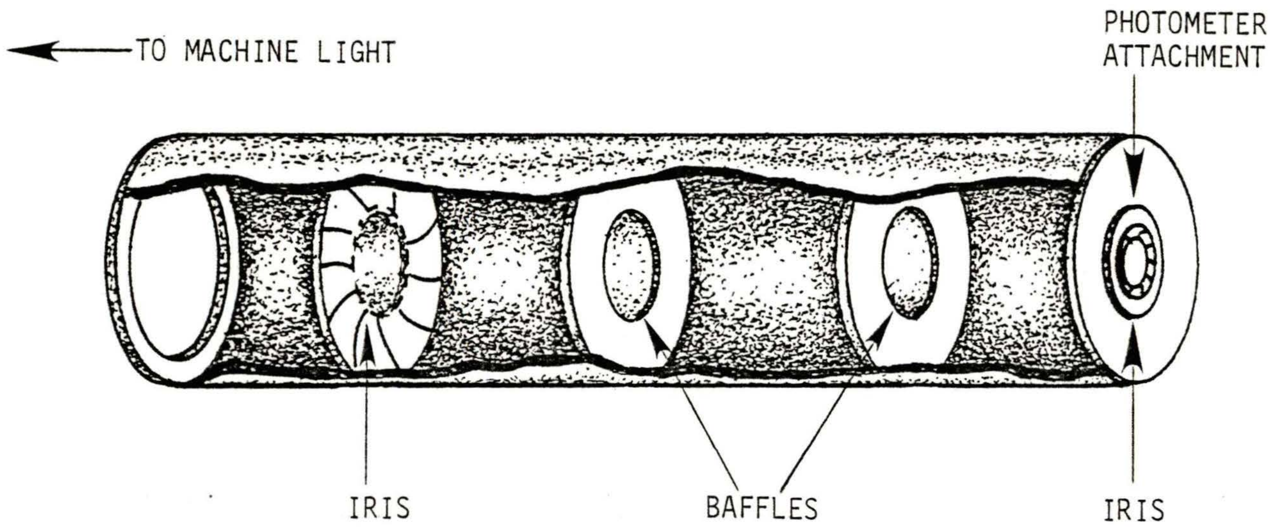
The photometer was used in conjunction with a specially designed light measurement tube. A cut away sketch of the tube is shown in Figure 3.1. The tube rests on a tripod, positioned at a visual attention location, and is aimed at the machine light. After adjusting the front iris of the tube so that an area slightly larger than the machine light is visible, the photometer is attached to the rear of the tube and the amount of light reaching the photometer is measured.

The tube is constructed to eliminate all stray light from reaching the photometer. Only the illumination emitted from the machine light, or stray light reflected off the face of the machine light, is measured. The use of this measurement tube and the procedure described next permits one to measure the illumination level of machine lights in daylight conditions.

3.1.3 Procedure. The following procedure was carried out at each visual attention location (VAL). All cars were measured assuming an outby direction of travel. In addition, the end driven machines were also measured assuming an inby direction.

The measurement tube was positioned at the VAL and aimed at one of the machine lights. The machine light was draped (shaded) with black velvetine cloth to reduce stray light reaching the face of the machine light. The illumination level was then measured using the photometer. The machine light was then turned off and the measurement repeated. This second measure was used to correct the lights-on reading for stray light reflected off the face of the machine light. The same procedure, lights-on, lights-off, was repeated aiming the light tube at the second machine light (shuttle cars have only two lights on both inby and outby sides).

The illumination values to be reported are conservative, in so far as they do not include machine light reflected from floor, roof, or ribs. However, since the reflectivity of coal is very low (approximately 3 percent), not much additional light would be added.



Length: 61 cm

Diameter: 15.2 cm

Inside: black velvetine

Figure 3.1. Cut away view of light measuring tube used to measure machine light illumination levels.

3.2 Results

Table 3.1 presents, for each VAL, the mean, standard deviation, maximum, and minimum illumination levels (in foot-candles) assuming an outby direction of travel. The sample size is six. Table 3.2 presents the same data for the inby direction of travel, however, the data are based only on the three end driven cars. The VALs located at seam height ("SH" in the up-down dimension) caused difficulty, in so far as the tripod arrangement could not reach the required height with four of the cars. The tables, therefore, report data from only those cars from which it could be measured.

Several things stand out in the tables. First, there is enormous variability in illumination between cars at a given VAL, especially for the outby direction of travel. The maximum values are usually an order of magnitude larger than the minimum values. Second, the mean illumination levels do not differ greatly as a function of vertical height at any given location (e.g., mean illumination at VALs 32, 33, and 34 are similar, as are VALs 8, 9, 10, and 11).

A comparison was made between illumination levels in the outby and inby directions of travel for the three cars for which data were available for both the directions, i.e., the end driven cars. Of the 54 VALs, illumination levels were higher in the inby direction on 26 VALs and higher in the outby direction on 24 VALs. (Four VALs receive no illumination in either direction.) It appears, therefore, that illumination levels are not consistently higher or lower in one direction of travel or the other.

In addition to the inby versus outby analysis, high seam and low seam cars were compared. So as not to confound the analysis, high and low seam cars were compared using the outby direction of travel only. There were three high and three low seam cars for which outby illumination levels were available.

Of the 54 VALs, 43 showed higher mean illumination levels from low seam cars, seven favored high seam cars, and four showed no illumination from any car. Due to the small sample size, statistical tests between high and low seam cars showed only eight VALs reliably different at the 0.10 level. This is very close to what would be expected by chance, i.e., ten percent of 54. However, given the preponderance of VALs with higher illumination levels from low seam cars, it seems safe to say that at least for the limited sample used here, low seam cars provide higher levels of illumination at the VALs than do high seam cars. One explanation for the superiority of low seam cars is that the VALs are compressed in the vertical dimension with low seam cars. The overall height of a low seam car might be less than 90 cm, thus all the VALs, except those at seam height, are within this space. Since the headlights are also within this space, the VALs are closer to the focus of the light than is the case with larger, high seam machines.

To more conveniently summarize the illumination data, the mean illumination was computed at each x-y VAL coordinate by averaging the illumination levels for all VALs positioned at the same location, but differing in vertical position. This procedure is justified because the data in Tables

Table 3.1. Illumination Data (foot-candles) for Outby Direction of Travel (N=6)

X-Y COORDINATE CODE	NO.	FORE-AFT (X COORDINATE)	SIDE-TO-SIDE (Y COORDINATE)	UP-DOWN (Z COORDINATE)	MEAN	STD DEV	MIN	MAX
A	1	RE	MCL	OEH	0.0	0.0	0.0	0.0
	2	RE	MCL	HMP	0.0	0.0	0.0	0.0
B	3	OH	MCL	OEH	0.0	0.0	0.0	0.0
	4	OH	MCL	HMP	0.0	0.0	0.0	0.0
C	5	OH + 1/2 NSD	WMP(SS) + 3'	OEH	4.33	6.42	0.00	11.72
D	6	FE + 2'	WMP(SS) + 1/2 NSD	Floor	0.48	0.68	0.03	1.83
	7	FE + 2'	WMP(SS) + 1/2 NSD	HMP	0.62	0.71	0.06	1.72
E	8	FE + 2'	WMP(SS) + 3'	Floor	4.42	4.91	0.70	11.55
	9	FE + 2'	WMP(SS) + 3'	MMH	4.61	5.55	0.56	13.32
	10	FE + 2'	WMP(SS) + 3'	OEH	3.93	4.69	0.45	10.62
	11	FE + 2'	WMP(SS) + 3'	HMP	3.57	3.92	0.11	8.31
F	12	FE	MCL	MMH	2.85	3.24	0.20	9.01
	13	FE	MCL	OEH	3.96	7.34	0.25	18.90
	14	FE	MCL	HMP	3.33	5.74	0.17	13.49
	15	FE	MCL	SH or MBH	0.18	0.15	0.56	0.39
G	16	FE + 2'	WMP(OS) + 2'	Floor	10.17	9.99	2.99	29.72
	17	FE + 2'	WMP(OS) + 2'	MMH	10.59	10.84	2.14	31.30
	18	FE + 2'	WMP(OS) + 2'	HMP	8.61	7.42	0.20	17.94
H	19	FE + 2'	WMP(OS) + 1/2 NSD	Floor	0.54	0.58	0.06	1.47
	20	FE + 2'	WMP(OS) + 1/2 NSD	MMH	0.68	0.66	0.09	1.80
	21	FE + 2'	WMP(OS) + 1/2 NSD	OEH	0.70	0.61	0.09	1.58
	22	FE + 2'	WMP(OS) + 1/2 NSD	HMP	0.47	0.37	0.06	0.85
I	23	FE + 1/2 NSD	WMP(OS) + 1/2 NSD	Floor	4.01	3.67	0.56	9.18
	24	FE + 1/2 NSD	WMP(OS) + 1/2 NSD	OEH	4.27	4.52	0.45	11.38
	25	FE + 1/2 NSD	WMP(OS) + 1/2 NSD	HMP	4.10	3.82	0.48	9.63
J	26	FE + 1/2 NSD	WMP(OS) + 2'	Floor	114.08	81.84	41.49	267.05
	27	FE + 1/2 NSD	WMP(OS) + 2'	HMP	119.56	77.70	27.02	204.85
K	28	FE + 1/2 NSD	MCL	MMH	448.68	431.22	113.24	1264.33
	29	FE + 1/2 NSD	MCL	SH	178.85	126.50	64.00	314.32
L	30	FE + 1/2 NSD	OCL	Floor	564.32	344.58	153.58	950.37
	31	FE + 1/2 NSD	OCL	SH	259.57	237.69	33.49	541.62
M	32	FE + 1/2 NSD	WMP(SS) + 3'	Floor	82.32	77.22	18.93	220.74
	33	FE + 1/2 NSD	WMP(SS) + 3'	MMH	83.51	82.50	29.02	230.40
	34	FE + 1/2 NSD	WMP(SS) + 3'	HMP	78.96	59.21	25.97	157.33
N	35	FE + 1/2 NSD	WMP(SS) + 1/2 NSD	Floor	2.44	2.24	0.62	5.78
	36	FE + 1/2 NSD	WMP(SS) + 1/2 NSD	HMP	2.56	2.33	0.65	5.72
O	37	FE + NSD	WMP(SS) + 1/2 NSD	Floor	11.64	9.11	2.84	25.38
	38	FE + NSD	WMP(SS) + 1/2 NSD	OEH	9.62	7.75	2.73	23.41
	39	FE + NSD	WMP(SS) + 1/2 NSD	HMP	10.91	8.17	4.11	22.51
P	40	FE + NSD	WMP(SS) + 2'	Floor	141.26	126.70	23.10	337.48
	41	FE + NSD	WMP(SS) + 2'	OEH	151.79	146.46	41.97	381.36
	42	FE + NSD	WMP(SS) + 2'	HMP	138.55	132.41	24.48	290.43
Q	43	FE + NSD	OCL	MMH	499.54	580.24	46.23	1578.22
	44	FE + NSD	OCL	HMP	421.32	513.90	47.33	1302.81
R	45	FE + NSD	MCL	Floor	279.89	123.96	87.44	424.80
	46	FE + NSD	MCL	MMH	442.41	371.03	58.71	1067.39
	47	FE + NSD	MCL	OEH	431.55	366.29	80.59	1066.49
	48	FE + NSD	MCL	HMP	400.31	334.42	74.57	880.76
S	49	FE + NSD	WMP(OS)	Floor	151.19	66.33	61.18	231.33
	50	FE + NSD	WMP(OS)	OEH	430.11	467.22	57.30	1298.05
	51	FE + NSD	WMP(OS)	HMP	444.30	387.37	53.95	864.42
T	52	FE + NSD	WMP(OS) + 1/2 NSD	Floor	13.14	9.11	2.31	22.08
	53	FE + NSD	WMP(OS) + 1/2 NSD	OEH	15.85	12.10	0.96	28.51
	54	FE + NSD	WMP(OS) + 1/2 NSD	HMP	16.37	12.86	0.22	27.07

Table 3.2. Illumination Data (foot-candles) for Inby Direction of Travel (N=3)

X-Y COORDINATE CODE	NO.	FORE-AFT (X COORDINATE)	SIDE-TO-SIDE (Y COORDINATE)	UP-DOWN (Z COORDINATE)	MEAN	STD DEV	MIN	MAX
A'	1	RE	MCL	OEH	0.0	0.0	0.0	0.0
	2	RE	MCL	HMP	0.0	0.0	0.0	0.0
B'	3	OH	MCL	OEH	0.0	0.0	0.0	0.0
	4	OH	MCL	HMP	0.0	0.0	0.0	0.0
C'	5	OH + 1/2 NSD	WMP(SS) + 3'	OEH	0.0	0.0	0.0	0.0
D'	6	FE + 2'	WMP(SS) + 1/2 NSD	Floor	0.33	0.23	0.11	0.56
	7	FE + 2'	WMP(SS) + 1/2 NSD	HMP	0.28	0.08	0.22	0.34
E'	8	FE + 2'	WMP(SS) + 3'	Floor	2.09	0.68	1.44	2.79
	9	FE + 2'	WMP(SS) + 3'	MMH	2.02	1.38	0.65	3.41
	10	FE + 2'	WMP(SS) + 3'	OEH	1.26	0.94	0.59	1.92
	11	FE + 2'	WMP(SS) + 3'	HMP	1.97	0.32	1.75	2.20
F'	12	FE	MCL	MMH	5.14	6.59	0.65	12.71
	13	FE	MCL	OEH	4.86	6.33	0.91	12.17
	14	FE	MCL	HMP	6.44	7.63	1.04	11.83
	15	FE	MCL	SH or MBH	1.13	0.0	1.13	1.13
G'	16	FE + 2'	WMP(OS) + 2'	Floor	6.07	3.09	2.85	9.01
	17	FE + 2'	WMP(OS) + 2'	MMH	3.26	2.34	0.65	5.18
	18	FE + 2'	WMP(OS) + 2'	HMP	4.27	0.50	3.92	4.62
H'	19	FE + 2'	WMP(OS) + 1/2 NSD	Floor	0.24	0.23	0.0	0.45
	20	FE + 2'	WMP(OS) + 1/2 NSD	MMH	0.33	0.28	0.06	0.62
	21	FE + 2'	WMP(OS) + 1/2 NSD	OEH	0.31	0.24	0.09	0.56
	22	FE + 2'	WMP(OS) + 1/2 NSD	HMP	0.47	0.22	0.31	0.62
I'	23	FE + 1/2 NSD	WMP(OS) + 1/2 NSD	Floor	0.58	0.64	0.0	1.27
	24	FE + 1/2 NSD	WMP(OS) + 1/2 NSD	OEH	0.99	0.19	0.76	1.10
	25	FE + 1/2 NSD	WMP(OS) + 1/2 NSD	HMP	1.07	0.20	0.93	1.21
J'	26	FE + 1/2 NSD	WMP(OS) + 2'	Floor	74.37	13.44	60.62	87.47
	27	FE + 1/2 NSD	WMP(OS) + 2'	HMP	53.20	73.28	1.38	105.02
K'	28	FE + 1/2 NSD	MCL	MMH	326.59	111.50	222.40	444.18
	29	FE + 1/2 NSD	MCL	SH	109.78	0.0	109.78	109.78
L'	30	FE + 1/2 NSD	OCL	Floor	617.92	296.08	331.90	923.13
	31	FE + 1/2 NSD	OCL	SH	86.37	0.0	86.37	86.37
M'	32	FE + 1/2 NSD	WMP(SS) + 3'	Floor	19.71	16.71	2.31	35.64
	33	FE + 1/2 NSD	WMP(SS) + 3'	MMH	53.44	39.74	19.52	97.16
	34	FE + 1/2 NSD	WMP(SS) + 3'	HMP	48.64	39.54	20.68	76.59
N'	35	FE + 1/2 NSD	WMP(SS) + 1/2 NSD	Floor	1.19	0.87	0.51	2.17
	36	FE + 1/2 NSD	WMP(SS) + 1/2 NSD	HMP	0.99	0.16	0.87	1.10
O'	37	FE + NSD	WMP(SS) + 1/2 NSD	Floor	5.89	3.78	3.61	10.25
	38	FE + NSD	WMP(SS) + 1/2 NSD	OEH	8.32	4.40	3.38	11.80
	39	FE + NSD	WMP(SS) + 1/2 NSD	HMP	10.66	9.66	3.83	17.50
P'	40	FE + NSD	WMP(SS) + 2'	Floor	202.93	187.36	51.69	412.52
	41	FE + NSD	WMP(SS) + 2'	OEH	132.65	87.17	52.26	225.30
	42	FE + NSD	WMP(SS) + 2'	HMP	111.34	85.87	50.62	172.06
Q'	43	FE + NSD	OCL	MMH	313.65	300.09	106.40	657.77
	44	FE + NSD	OCL	HMP	268.43	225.37	109.07	427.79
R'	45	FE + NSD	MCL	Floor	285.80	215.99	150.00	534.86
	46	FE + NSD	MCL	MMH	321.78	243.04	148.65	599.63
	47	FE + NSD	MCL	OEH	328.34	229.76	159.92	590.08
	48	FE + NSD	MCL	HMP	359.00	288.47	155.02	562.98
S'	49	FE + NSD	WMP(OS)	Floor	175.93	101.72	91.41	288.83
	50	FE + NSD	WMP(OS)	OEH	168.65	88.89	98.37	268.57
	51	FE + NSD	WMP(OS)	HMP	186.27	129.42	94.76	277.78
T'	52	FE + NSD	WMP(OS) + 1/2 NSD	Floor	5.93	3.95	3.10	10.45
	53	FE + NSD	WMP(OS) + 1/2 NSD	OEH	7.34	4.11	4.14	11.97
	54	FE + NSD	WMP(OS) + 1/2 NSD	HMP	6.27	0.38	6.00	6.54

3.1 and 3.2 reveal fairly consistent illumination levels with respect to vertical height at any given x-y coordinate. Figure 3.2 presents these average levels for both the inby and outby directions of travel. The letters in Figure 3.2 correspond to the x-y coordinate codes shown in Tables 3.1 and 3.2. Figure 3.3 presents a more graphic depiction of the data shown in Figure 3.2.

The MSHA underground coal mine illumination requirements for shuttle cars specify that (Section 75.1719-1(e)(6), Title 30, Code of Federal Regulations):

a. Lighting fixtures shall be installed on each end of such other self-propelled equipment which will illuminate face or rib coal surfaces within 10 feet of the front and the rear of the machine to a surface brightness of not less than 0.06 footlamberts.

b. The height and width of the area of the coal surface that is required to be illuminated shall be equal to the height and width of the machine on which the light fixtures are installed.

   When determining the height and width of the coal surface to be illuminated as provided in Section 75.1719-1(e)(6)(ii), the maximum height of the equipment (including sideboards, cabs and canopies) and the maximum width of the equipment (including bumpers, tires, cabs and canopies) shall be used. The height and width of the coal surface that is required to be illuminated will be the same in both directions of travel.

If we accept a nominal reflectivity value for coal of three percent, then two foot-candles of illumination are needed to produce the required luminance (surface brightness) of 0.06 footlamberts. Figure 3.3 includes the 2 footcandle boundry. As can be seen in terms of average illuminations, this sample of cars meets and even exceeds the MSHA illumination requirements. The illumination requirements, however, were not based on the VAL concept and hence several peripheral VALs receive inadequate levels of illumination to provide 0.06 foot lamberts of luminance, i.e., D and H in the outby direction, and D', E', H', I', and N' in the inby direction.

The average values presented in Figure 3.2 tend to mask the large variations in illumination levels present between machines. To capture, and present this, the average illumination at each x-y coordinate was computed for each car measured. The percentage of cars with less than two footcandles average illumination at each x-y coordinate was then computed. These percentages are graphically depicted in Figure 3.4. At each x-y coordinate, a circle is used to represent the proportion of cars with illumination levels above and below two footcandles.

As can be seen from Figures 3.3 and 3.4, inadequate levels of illumination tend to be found at the following x-y coordinates:

outby: B, C, D, E, F, H, I, and N
inby: B', C', D', E', F', H', I', and N'

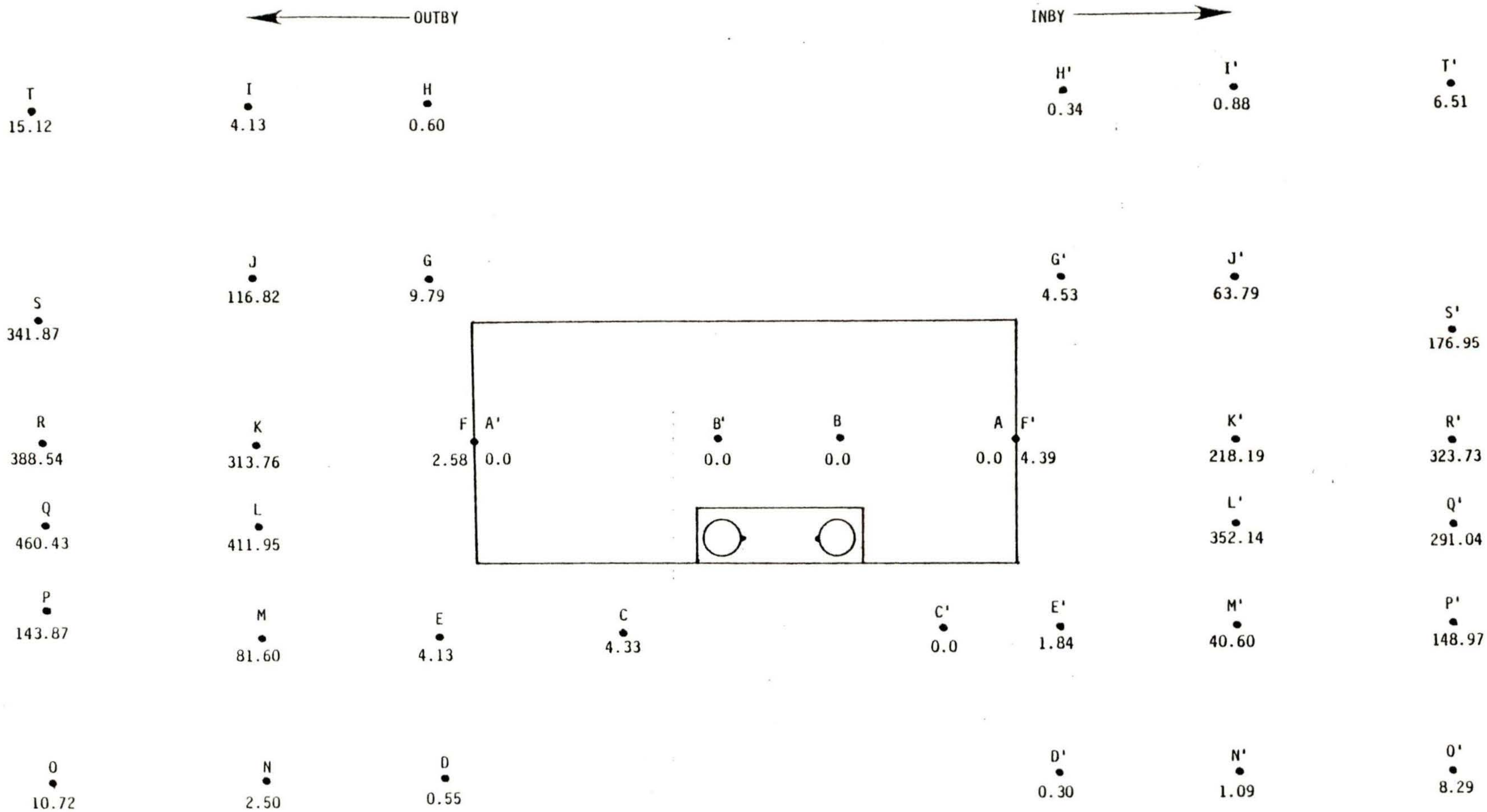


Figure 3.2. Mean illumination levels (foot-candles) for inby (A'...T') and outby (A...T) direction of travel.

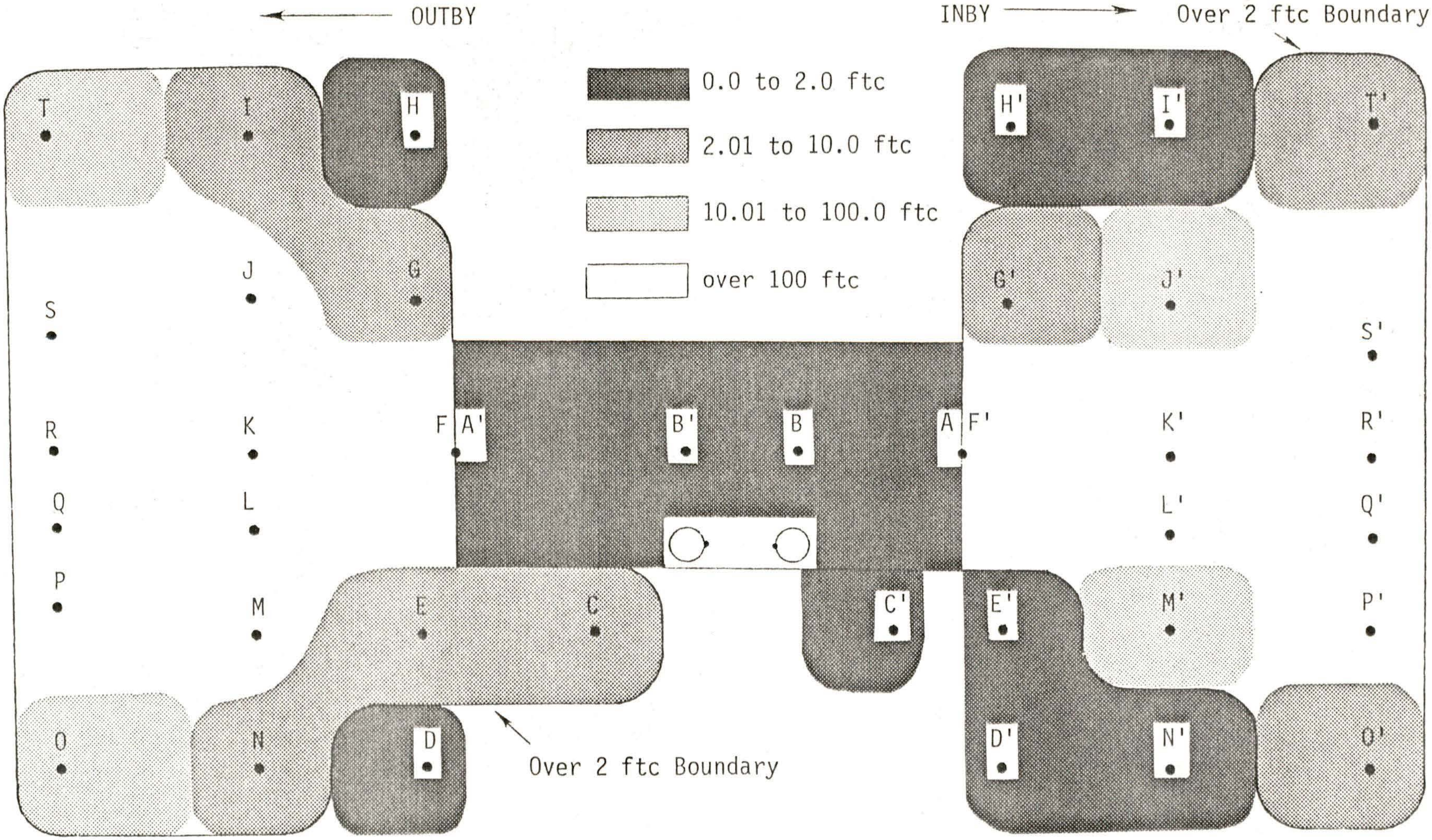


Figure 3.3. Pictorial representation of mean illumination levels for inby (A'...T') and outby (A...T) directions of travel.

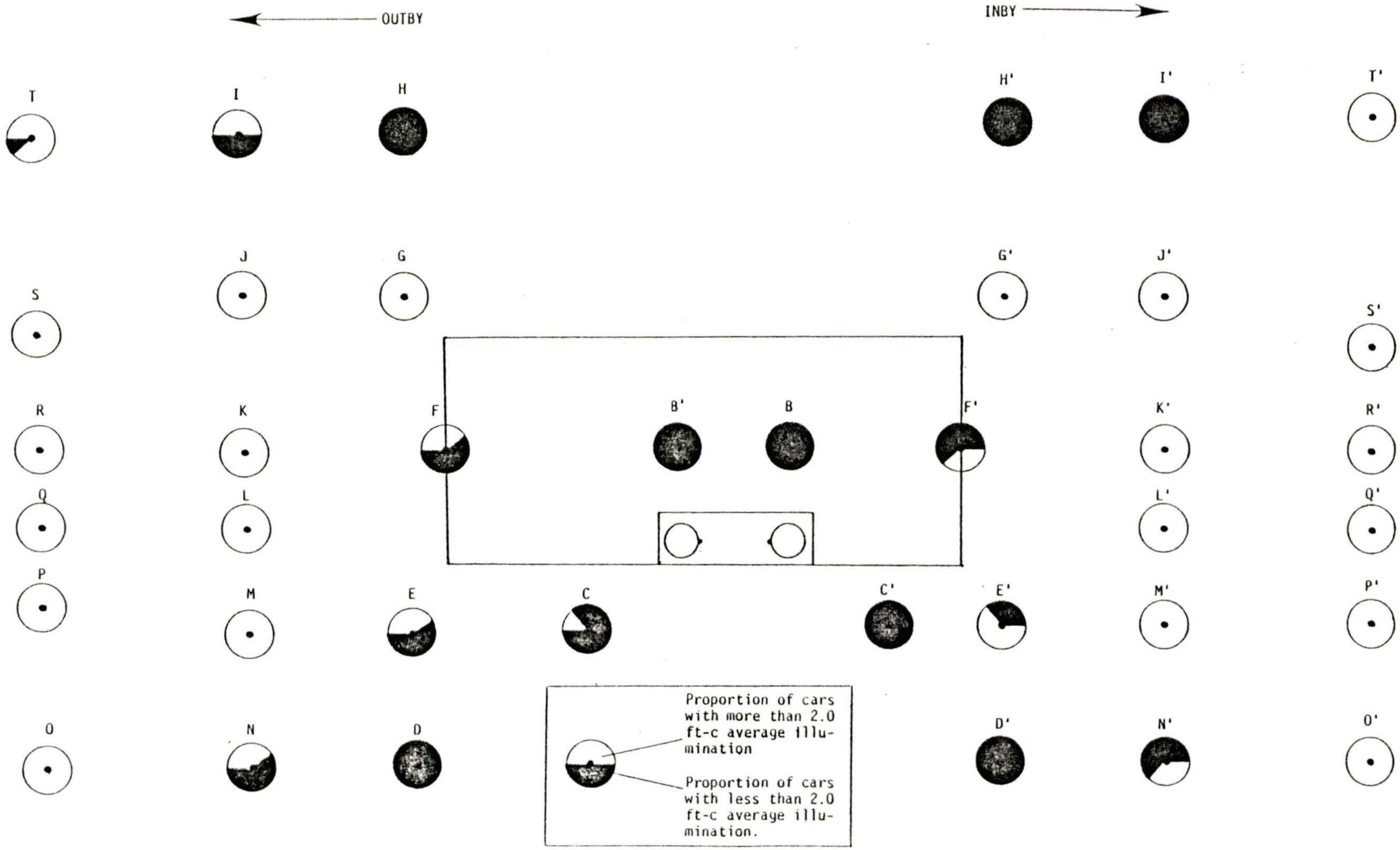


Figure 3.4. Proportion of cars with average illumination levels above and below 2.0 ft-c.

The B and B' locations are located inside the conveyor area of the car, and one cannot expect machine lights to illuminate them. The C, C', D, D', E, E', N, and N' locations are located on the same side as the operator and could be illuminated by the operator's caplamp. Thus, although there is inadequate machine illumination at these locations, this may not be critical since the caplamp can supply the necessary illumination. Locations F, F', H, H', I, and I', however, in many instances do not receive adequate levels of machine-light illumination and are located at the center and opposite sides of the machine, thereby, reducing the likelihood that the caplamp would serve as an alternate illuminance source. As discussed in Section 2.0, these same locations are also not visible from a majority of cars. The implications of this are discussed in Section 4.0.

3.3 Conclusions

The analysis of machine-light illumination levels at the VALs revealed that, as a whole, illumination levels meet and often exceed the MSHA shuttle car illumination requirements. Inadequate illumination levels were recorded for VALs located on the side of the machine opposite the operator. It is unlikely that caplamp illumination would rectify the problem. In contrast, although inadequate levels of machine-light illuminance were recorded for some VALs on the same side of the machine as the operator, it is likely that caplamp illumination would solve the problem.

The analysis suggested that there was no consistent tendency for illuminance levels to be higher in the outby or inby direction of travel. However, illumination levels at the VALs were consistently higher for low seam cars than for high seam cars. This is probably due to the lower overall height of low seam cars.

4.0 RECOMMENDATIONS

The results from Section 2.0 demonstrate the sensitivity of the HERMI/VAL methodology in determining visibility from underground equipment. Several variables were identified as having a statistically reliable effect on total visibility, i.e., eye position, direction of travel, and type of car (end versus center). When the variables were controlled, no effect of canopy or seam height of the car was found.

The results of Sections 2.0 and 3.0 uncovered important "blind spots" in the operator's field of view. The blind areas are on the opposite side of the machine from the operator and ahead of the machine. VALs located in this area at floor height were not visible from any of the cars measured. VALs above floor height in this area, however, were visible from most machines but only when the canopy (i.e., eye position) was in the highest position. Section 3.0, however, found that inadequate levels of illumination (i.e., less than 2.0 footcandles) were common at these VALs. Hence, even if they can be seen, there may not be enough light available to permit adequate vision.

These blind area VALs were included to represent areas where obstacles might be located, and hence are very important. These VALs should, therefore, not be eliminated from the list, but additional design efforts made to improve visibility to these areas.

4.1 Recommendations

1. Promote the concept of VALs for visibility assessment and for setting illumination requirements.

2. Explore methods for improving visibility in the blind areas identified. Although it is beyond the scope of this project to develop such methods, the following are suggested. These suggestions are made without detailed analyses of feasibility or cost.

   a. Use of an operator controlled opposite-side light to direct illumination to the blind areas. Envisioned is a control in the cab which permits the operator to aim the opposite-side light, much like the inside side-view-mirror control in an automobile.

   b. Lower the profile of cars, such that even in the low canopy position, the operator's eye height is above the median machine height.

   c. Use a system of mirrors and/or lenses to provide the operator with visual access to the blind areas.

It is recognized that there are problems inherent in these suggestions. However, they should not be abandoned, out of hand, until concerted efforts are made to reduce the problems and assess the cost benefits of the designs.

5.0 DETERMINING VISIBILITY FROM UNDERGROUND MINING EQUIPMENT USING THE HERMI (MARK II) AND VISUAL ATTENTION LOCATION METHODOLOGY: A PROCEDURES MANUAL

5.1 Introduction

The purpose of this chapter is to present the procedure for visibility evaluation for mobile equipment. The chapter describes the evaluation procedure; justification of the procedures is contained in Sanders and Kelley (1981), and in some degree, the previous sections of this report.

The procedure is centered around a human eye reference measurement instrument (HERMI) and specific visual attention locations (VALs). HERMI is a device that represents the eye positions of the 5th percentile female and 95th percentile male performing reasonable neck and trunk flexion. HERMI is placed in the operator's cab, simulating the position of the operator. At each visual attention location, the evaluator takes a picture of HERMI in the operator's cab. Examination of the photograph allows direct determination of whether the 5th and/or 95th percentile operator could see that location using a reasonable amount of the neck and/or trunk flexion. An alternative to photography is to position a sight tube at the visual attention location and have an observer report what parts of HERMI are visible. The disadvantage of this, of course, is that no permanent photographic record is made.

VALs are locations which equipment operators need to see to operate their equipment in a safe and efficient manner. Each VAL contains one or more important visual features. These locations were determined by conducting extensive task analyses of mining equipment operations (Sanders and Kelley, 1981).

The procedure to be presented in the remainder of this chapter centers around the HERMI device. Because of this central role, it will be of benefit to the user to understand the rationale and construction features of HERMI. Figure 5.1 shows front and side views of HERMI. The two arcs on HERMI represent the eye positions for the 5th percentile female (lower arc) and 95th percentile male (upper arc) in a relaxed (slumped) sitting posture. The anthropometric data used to construct HERMI represent military personnel as taken from Human Engineering Design Data Digest (HEL, 1978) and Anthropometric Data Application Mannikin (Rogers, 1976). Neck and torso flexion was taken as 35 degrees as shown in Figure 5.2. The 35 degrees value represents mean flexion from military populations. A Bureau of Mines project (Contract H0387022, Biomechanics in Low Coal) concluded that coal miners are not significantly different from military populations in terms of linear body dimensions, hence HERMI can be used in the context of coal mine equipment.

HERMI is constructed of square metal tubing and masonite eye rings. As configured, HERMI represents reasonable operator postures. An actual operator might lean forward to improve visibility or flex more than 35 degrees from side to side, however, it was decided that vehicles should not be designed to require such movement from the operator in order to see

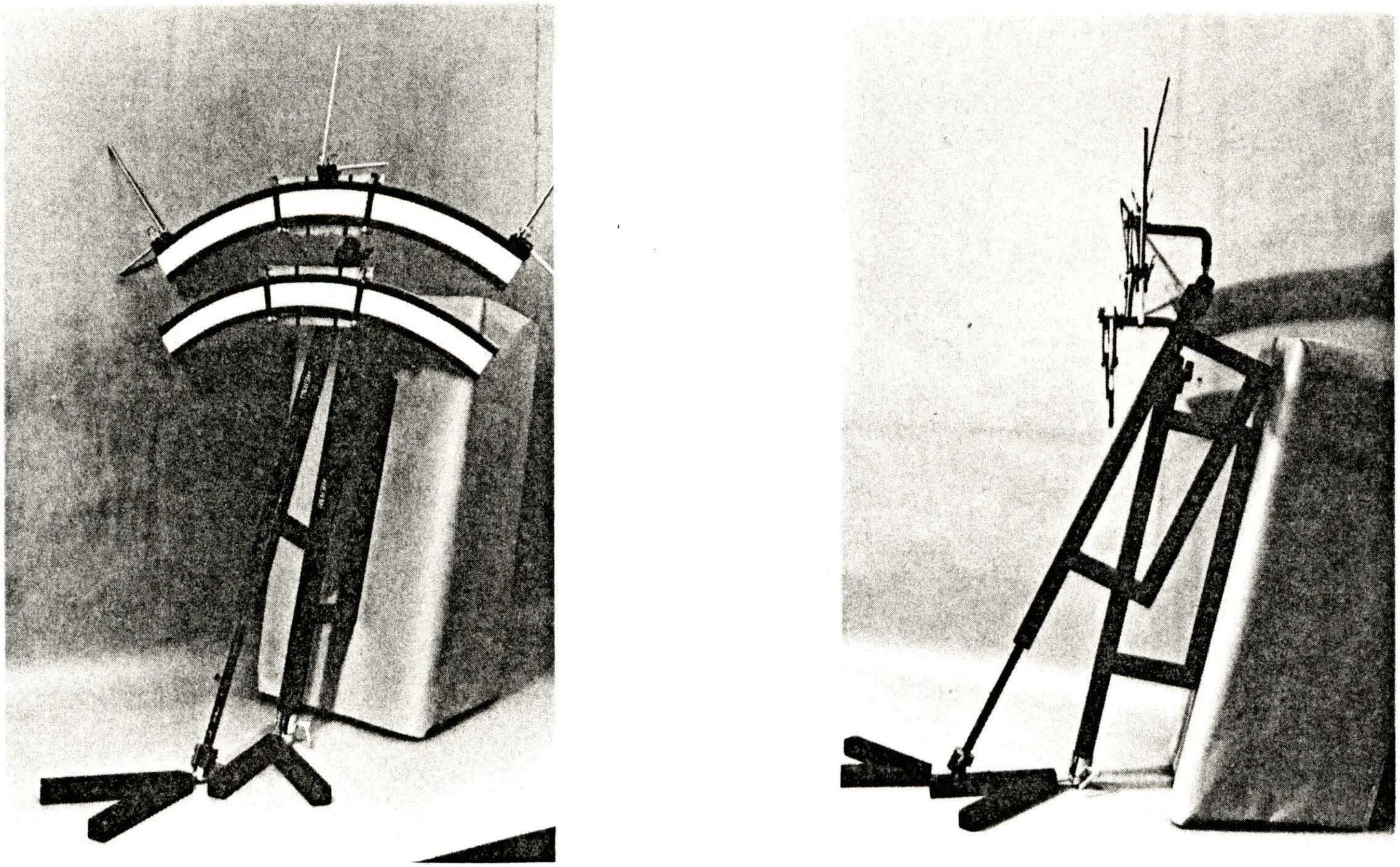


Figure 5.1. Front and side views of HERMI.

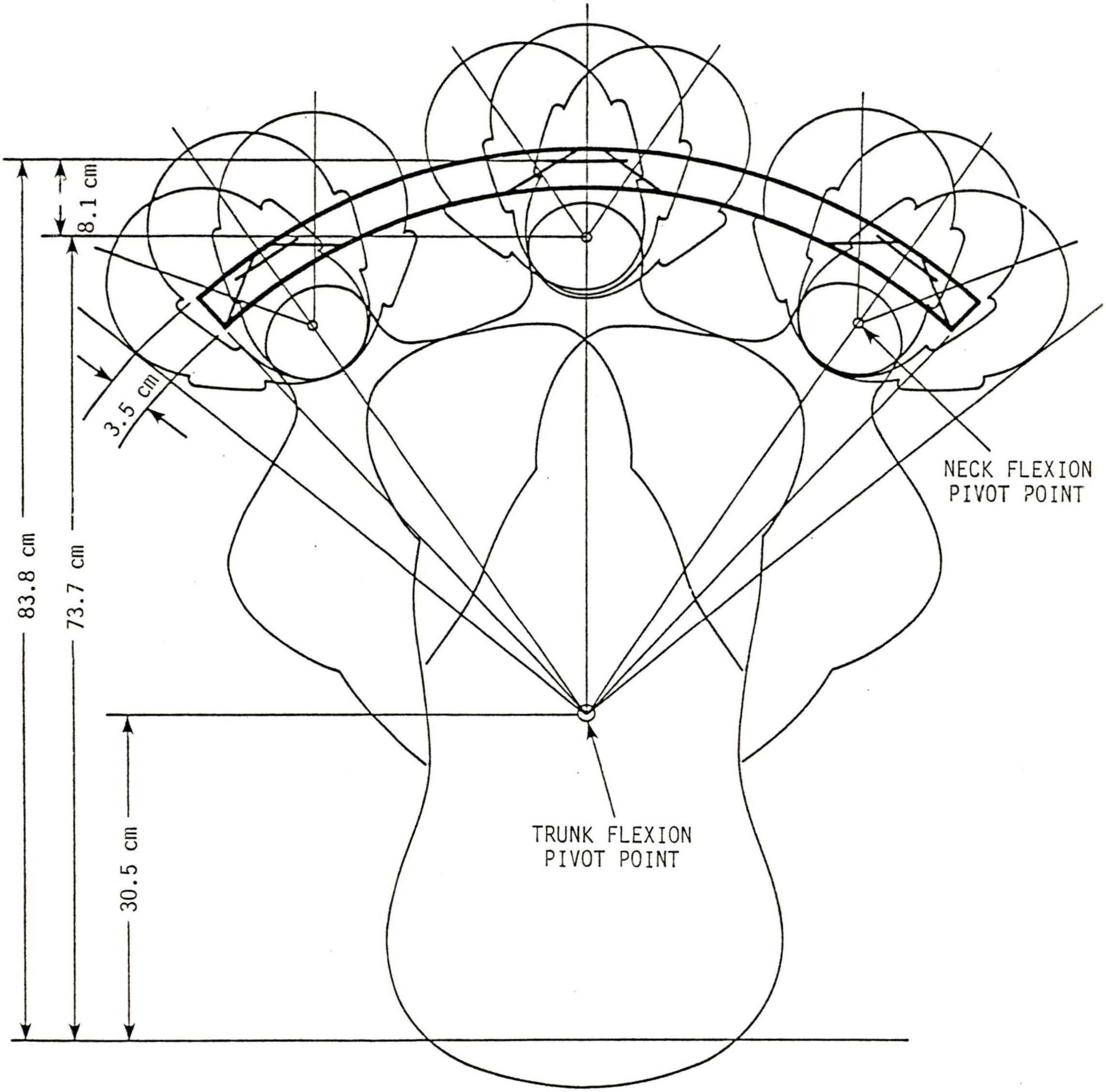


Figure 5.2. Representation of neck and trunk flexion and resulting eye arc used to construct HERMI.

important visual features. The 35 degrees flex angles were considered reasonable. It was assumed that the operator should be able to use a seat back provided without sacrificing visibility.

Several features of HERMI make it unique for underground mining equipment application. First, the eye arcs are jointed so that they can be oriented perpendicular to the ground for any seat back angle, from upright to full reclining. Further, the base and "spine" are also jointed to allow accommodation to any seat back angle. People in a partially reclined position will rotate their neck forward until their eyes are facing forward. HERMI can imitate this maneuver. Second, the eye arcs can be retracted toward the center line of HERMI. In the event an obstruction exists in a cab which would prevent torso flexion to the full 35 degrees to one side or the other, the eye arc can be shortened to represent the restricted space. At each end of each eye arc is a spring clip which represents the distance from the side of the head to the eye. Thus, when the spring is extended against an obstruction, HERMI is simulating the side of the head against the obstruction and, hence, the eye arc is accurate. Third, HERMI is constructed with two separate bodies representing the 5th and 95th percentile body heights. Thus, when the canopy of the mining machine is set in its lowest position, the 95th percentile body may sit at an angle to the back rest of the seat while the 5th percentile body may remain upright, thus simulating the body postures typically assumed under a low canopy. Also, under a low canopy, the eye arcs will be closer together and, in extreme cases, they may be at the same height (only one HERMI body is needed for extreme cases). The HERMI bodies are also constructed with stand-offs to maintain the proper fore-aft placement of the eye arcs when the operator leans back against the seat. Fourth, the eye arc is marked as shown in Figure 5.3. Area A represents the position of the eyes with the neck and torso in a straight ahead orientation. Area B represents the eye positions if only the neck is flexed 35 degrees. The entire arc represents neck and torso flexion of 35 degrees. The slip springs, when placed in the positions shown in Figure 5.3, represent the additional space needed to account for the operator's forehead, helmet, caplamp, and caplamp cord.

An overview of the procedure for assessing visibility using HERMI is shown in Figure 5.4. At least two people are required to efficiently complete the procedure.

5.2 Step 1. Prepare the Mining Machine

Place the machine in an open area. The machine must be placed on a flat surface, and to facilitate access, it is recommended that a clear area, approximately 25 ft. in front, 15 ft. to each side, and 25 ft. to the rear be provided. Configure the equipment as follows:

A. Continuous Miner:

1. Canopy - the canopy supports should be set and bolted at a height equal to the height of the highest fixed machine part or at the lowest canopy support setting, whichever is highest.

2. Floating cab - at frame, ground clearance.

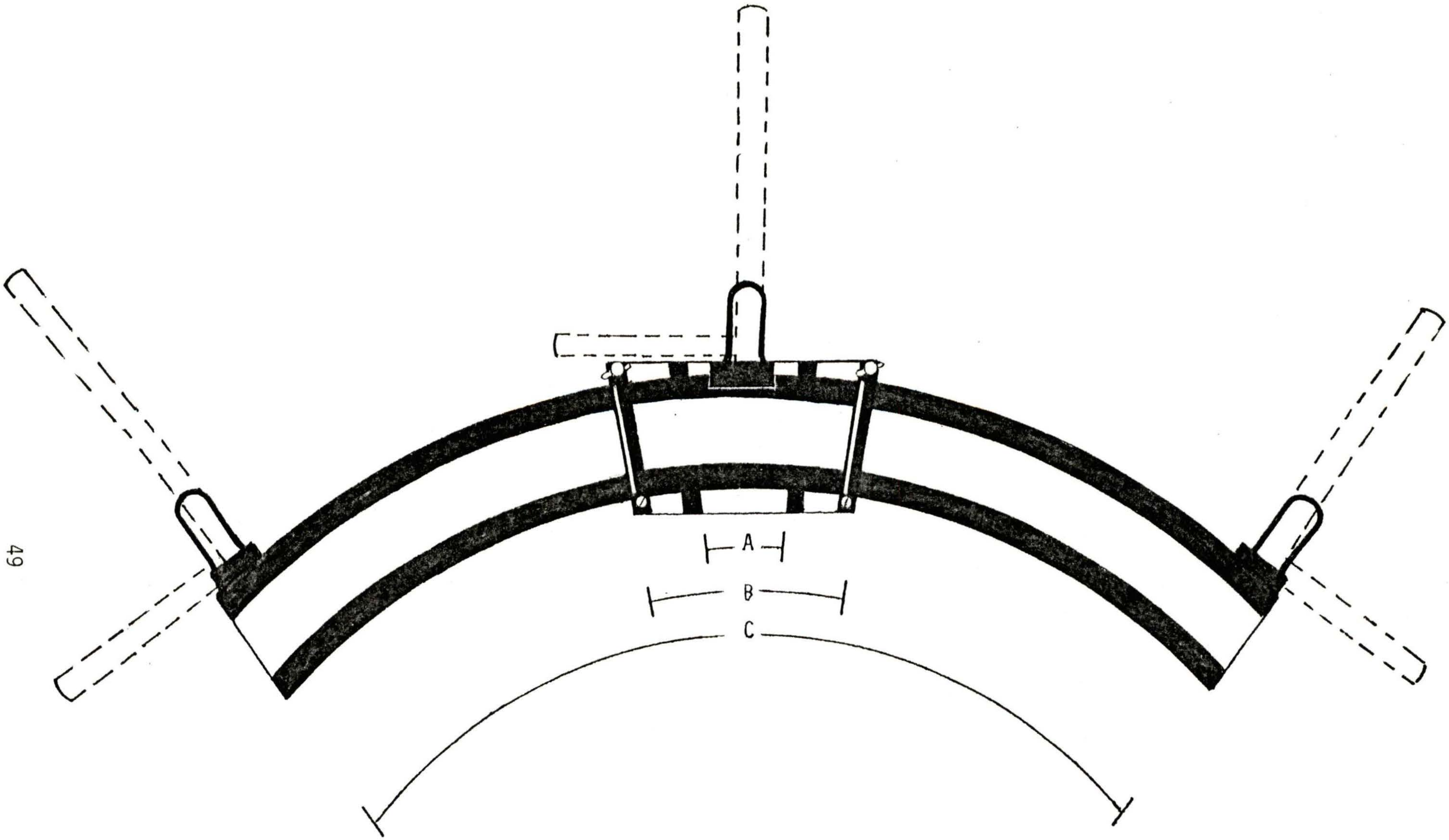


Figure 5.3. Schematic drawing of HERMI eye arc. See text for explanation of areas.

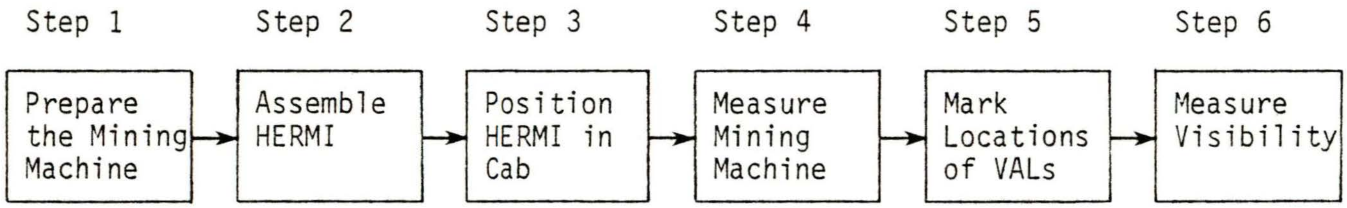


Figure 5.4. Overview of steps necessary to measure visibility using HERMI/VAL procedure.

3. Cutter head - tram position, at frame, ground clearance.

4. Gathering pan - tram position, at frame, ground clearance.

5. Tail boom - at frame, ground clearance, position at maximum boom swing for max boom swing pictures.

B. Shuttle Car:

1. Canopy - the canopy supports should be set and bolted at a height equal to the height of the highest fixed machine part or at the lowest canopy support setting, whichever is highest.

2. Floating cab - at frame, ground clearance.

3. Discharge boom (if adjustable) - median machine height.

C. Scoops:

1. Canopy - the canopy supports should be set and bolted at a height equal to the height of the highest fixed machine part or at the lowest canopy support setting, whichever is highest.

2. Floating cab - at frame, ground clearance.

3. Scoop - at frame, ground clearance.

4. Articulation - straight, aligned with center line of machine.

5. Bucket - at tram height.

Note, if desired, visibility can be assessed with other configurations in addition to those described above. For example, canopies, booms, and buckets can be raised or loads can be simulated in shuttle cars and scoops.

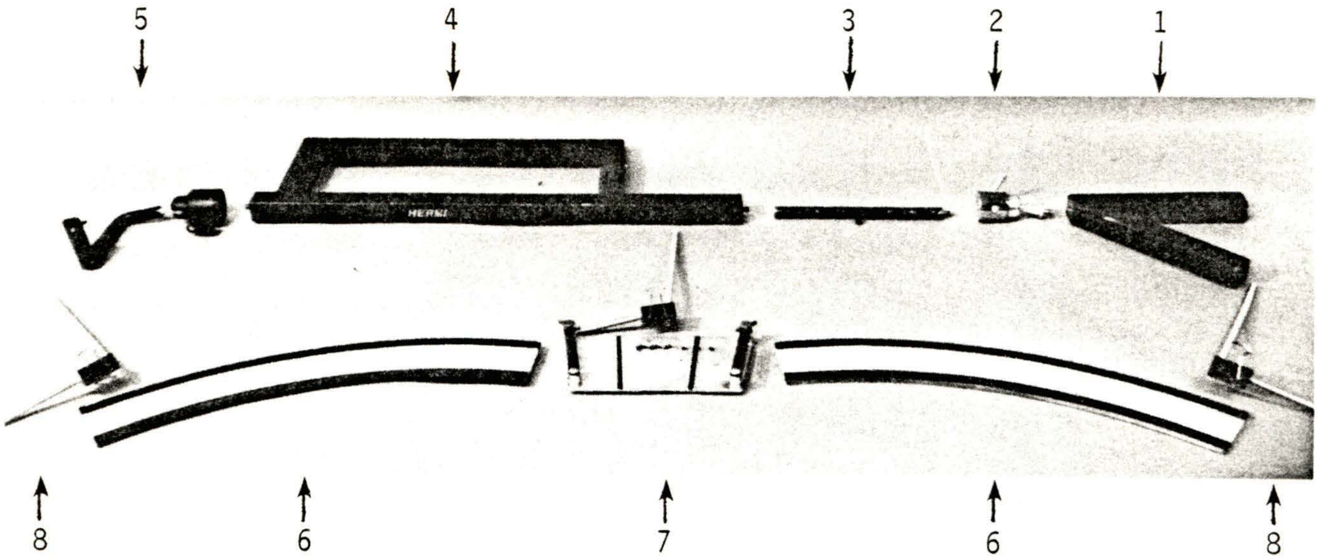
5.3 Step 2. Assemble HERMI

The parts needed to assemble HERMI are shown in Figure 5.5 for the 95th percentile device. Assemble the 95th percentile HERMI and repeat the steps to assemble the 5th percentile HERMI (omitting the extension bar). No tools are required. The procedure is as follows (number in parenthesis refers to items pictured in Figure 5.5):

1. Screw the stabilizing legs (1) onto the extension of the stabilizer joint (2).

2. Screw the extension bar(3) into the blunt end of the stabilizer joint (2).

3. Screw the long end of the body frame (4) into the extension bar (3). Position the stabilizer legs (1) at right angles to the body frame (4) and pointing forward. Note, the short side of the body frame (4) is the back of HERMI (refer to Figure 5.1).



ASSEMBLE HERMI

Parts List

Picture No.	Quantity	
1	2	Stabilizing legs
2	2	Stabilizer joints
3	1	Extension bar (95th percentile body)
4	2	Body frame
5	1	Neck joint (95th percentile body)
	1	Neck joint (5th percentile body)
6	2	Eye arcs (95th percentile, left and right)
	2	Eye arcs (5th percentile, left and right)
7	1	Eye arc plate (95th percentile)
	1	Eye arc plate (5th percentile)
8	3	Clip springs (95th percentile)
	3	Clip springs (5th percentile)

Figure 5.5. Parts used to assemble the 95th percentile HERMI

4. Screw the blunt end of the neck joint (5) onto the body frame (4). Swivel the neck joint (5) so that the neck extension points forward. Tighten the set screw of the joint. Note, the 95th percentile neck joint is slightly larger than the 5th percentile neck joint (refer to Figure 5.1).

5. Attach the 95th percentile eye arc plate (7) to the neck joint (5). Figure 5.6 shows the eye arc plate (7) and its three attachment settings for the neck joint (5). The settings are provided to compensate for the off-center positioning of the HERMI body frames when both the 95th and 5th percentile frames are used. The 95th and 5th percentile eye arcs must be centered and aligned. The three settings are provided for convenience so that the 5th percentile body frame can be placed either to the right or the left of the 95th percentile body frame. Attach the plates appropriately. The center setting is to be used when one body frame is used.

6. Slide the 95th percentile eye arcs (6) into the eye arc plate (7). Tighten the set screws on the plate to keep the eye arcs in position.

7. Attach the three "L" shaped clip springs (8) on the top center, left end, and right end of the eye arc. The lower spring should be extended outward on both ends of the eye arc.

8. Verify correct assembly by examining Figure 5.1.

5.4 Step 3. Position HERMI in the Cab

HERMI is constructed for use on non-compressible seats, such as is typically found in underground mobile equipment. If a compressible, padded seat is used, the seat must be compressed to compensate for HERMI's light weight. A 100 lb. weight or cord tied tightly around the seat, where HERMI's stabilizer joint rests on the pad, will adequately compress the seat.

HERMI must be positioned in the cab to simulate the actual operator's posture. Use the following procedure to position HERMI:

1. Position HERMI facing in the inby or outby direction.

2. Position the 95th percentile HERMI on the seat with the lower stabilizer legs angled flat on the seat. Duct tape may be used to position HERMI securely.

3. Tilt the eye arcs into a position that is facing forward, perpendicular to the ground, and at right angles to the fore-aft machine center line.

   a. The center clip spring can be touching the mining machine canopy, but must not be bent.

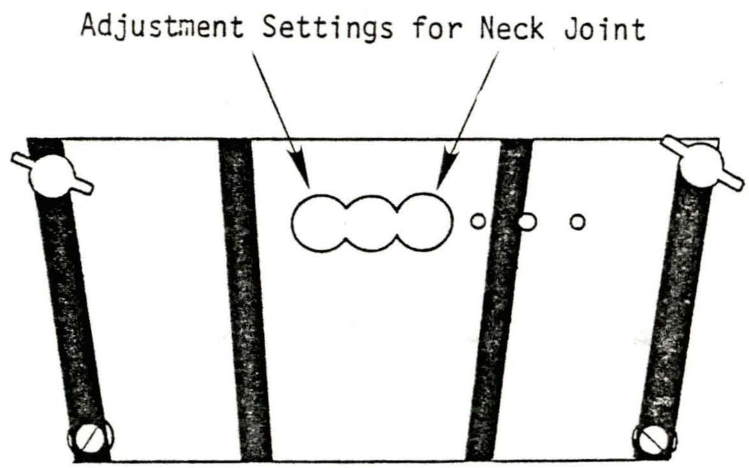


Figure 5.6. The 95th percentile eye arc plate and its three attachment settings.

b. Tighten the neck joint screw to prevent the joint from moving.

4. Adjust the eye arc for any side obstructions by moving the arcs inward.

   a. The end clip springs can touch but must not be bent by any side obstructions.

When the canopy of the mining machine is set at the lowest canopy position, it is likely that the back "stand-off" of the 95th percentile HERMI will be at a substantial angle to the seat backrest in order to position the eye arcs correctly. Moreover, when HERMI is placed in a low seam mining machine (30 in. machine height or less), it is likely that the 95th and 5th percentile eye arcs will be at the same heights. In this case, only the 95th percentile HERMI is needed.

5.5 Step 4. Measuring the Mining Machine

Several machine dimensions must be measured in order to determine the positions of the visual attention locations. The abbreviations for the measures (in parentheses) are used in specifying the visual attention locations and are used in the data sheets in this manual. Measure and record the following heights:

1. Median Machine Height (MMH): The vertical distance from the floor to the overall height of the main machine frame.

2. Highest Machine Point (HMP): The vertical distance from the floor to the highest vertical point on the machine.

3. Operator Eye Height (OEH): The vertical distance from the floor to a point midway between the 95th and 5th percentile eye arcs on HERMI.

4. Canopy Height (CH): The vertical distance from the floor to the highest point on the canopy.

5. Seam Height (SH): The anticipated minimum vertical distance from the floor to the roof in which it is reasonably likely the machine will be operated. (For purposes of this report, seam height was assumed to be 12 inches above the highest machine point. Although arbitrary, this value probably represents a reasonable clearance for many mines.)

6. Maximum Boom Height (MBH): Continuous miners only. The vertical distance from the floor to the highest point on the boom, with the boom positioned at its maximum height.

7. Maximum Cutter Head Height (MCH): Continuous miners only. The vertical distance from the floor to the highest point on the cutter head with the head positioned at its maximum height.

In addition to heights, the following reference points must be identified and marked on the floor:

1. Widest Machine Point(s) (WMP) - both sides: The widest machine point is that part of the machine that extends furthest from the centerline of the machine.

2. Front Edge (FE): The front edge of the machine is that part of the machine that extends furthest forward.

3. Rear Edge (RE): The rear edge of the machine is that part of the machine that extends furthest rearward.

4. Operator's Head Position (OH): The operator's head position is the location that the operator's head would occupy if a person of the 95th percentile body height sat in the cab seat. Once the 95th percentile HERMI is completely assembled and correctly placed in the cab seat, the top center of the eye arc plate may be used as the reference point.

5. Machine Center Line (MCL): The machine center line is a hypothetical line that bisects the machine lengthwise into two equal halfs.

6. Operator Center Line (OCL): The operator center line is a hypothetical line that bisects the cab seat (and thus an operator) into two equal halfs and is parallel to the machine center line.

7. Necessary Stopping Distance (NSD): The necessary stopping distance is the distance in which the mining machine can safely brake to a stop and is based on operator reaction time and the distance required to stop the machine traveling at maximum tram speed. Further discussion of necessary stopping distance can be found in Sanders and Kelley (1981). The necessary stopping distance is the basis for many of the visual attention locations (VALs). The following necessary stopping distances can be used (Sanders and Kelley, 1981):

   Scoops - 25 ft.
   Shuttle Cars - 20 ft.
   Continuous Miners - 10 ft.

5.6 Step 5. Mark Location of VALs

Tables 5.1, 5.2, and 5.3 list the VALs for shuttle cars, continuous miners, and scoops. Figures 5.7, 5.8, and 5.9 show the pattern of VALS for each of the machines. VALs are locations the operator needs to see, and can be specified by their position in three planes: fore-aft, side-to-side, and up-down. For example, shuttle car operators need to see the following VAL:

Fore-Aft	Side-to-Side	Up-Down
FE + NSD	OCL	MMH

Table 5.1. Recommended Visual Attention Locations for Shuttle Car Operations

No.	Fore-Aft	Side-to-Side	Up-Down	No.	Fore-Aft	Side-to-Side	Up-Down
1	RE	MCL	OEH	28	FE + 1/2 NSD	MCL	MMH
2	RE	MCL	HMP	29	FE + 1/2 NSD	MCL	SH
3	OH	MCL	OEH	30	FE + 1/2 NSD	OCL	Floor
4	OH	MCL	HMP	31	FE + 1/2 NSD	OCL	SH
5	OH + 1/2 NSD	WMP(SS) 3'	OEH	32	FE + 1/2 NSD	WMP(SS) + 3'	Floor
6	FE + 2'	WMP(SS) + 1/2 NSD	Floor	33	FE + 1/2 NSD	WMP(SS) + 3'	MMH
7	FE + 2'	WMP(SS) + 1/2 NSD	HMP	34	FE + 1/2 NSD	WMP(SS) + 3'	HMP
8	FE + 2'	WMP(SS) + 3'	Floor	35	FE + 1/2 NSD	WMP(SS) + 1/2 NSD	Floor
9	FE + 2'	WMP(SS) + 3'	MMH	36	FE + 1/2 NSD	WMP(SS) + 1/2 NSD	HMP
10	FE + 2'	WMP(SS) + 3'	OEH	37	FE + NSD	WMP(SS) + 1/2 NSD	Floor
11	FE + 2'	WMP(SS) + 3'	HMP	38	FE + NSD	WMP(SS) + 1/2 NSD	OEH
12	FE	MCL	MMH	39	FE + NSD	WMP(SS) + 1/2 NSD	HMP
13	FE	MCL	OEH	40	FE + NSD	WMP(SS) + 2'	Floor
14	FE	MCL	HMP	41	FE + NSD	WMP(SS) + 2'	OEH
15	FE	MCL	SH or	42	FE + NSD	WMP(SS) + 2'	HMP
			MBH	43	FE + NSD	OCL	MMH
16	FE + 2'	WMP(OS) + 2'	Floor	44	FE + NSD	OCL	HMP
17	FE + 2'	WMP(OS) + 2'	MMH	45	FE + NSD	MCL	Floor
18	FE + 2'	WMP(OS) + 2'	HMP	46	FE + NSD	MCL	MMH
19	FE + 2'	WMP(OS) + 1/2 NSD	Floor	47	FE + NSD	MCL	OEH
20	FE + 2'	WMP(OS) + 1/2 NSD	MMH	48	FE + NSD	MCL	HMP
21	FE + 2'	WMP(OS) + 1/2 NSD	OEH	49	FE + NSD	WMP(OS)	Floor
22	FE + 2'	WMP(OS) + 1/2 NSD	HMP	50	FE + NSD	WMP(OS)	OEH
23	FE + 1/2 NSD	WMP(OS) + 1/2 NSD	Floor	51	FE + NSD	WMP(OS)	HMP
24	FE + 1/2 NSD	WMP(OS) + 1/2 NSD	OEH	52	FE + NSD	WMP(OS) + 1/2 NSD	Floor
25	FE + 1/2 NSD	WMP(OS) + 1/2 NSD	HMP	53	FE + NSD	WMP(OS) + 1/2 NSD	OEH
26	FE + 1/2 NSD	WMP(OS) + 2'	Floor	54	FE + NSD	WMP(OS) + 1/2 NSD	HMP
27	FE + 1/2 NSD	WMP(OS) + 2'	HMP				

Table 5.2. Recommended Visual Attention Locations for Continuous Miner Operations

No.	Fore-Aft	Side-to-Side	Up-Down	No.	Fore-Aft	Side-to-Side	Up-Down
1	FE + NSD	WMP(OS) + 5'	OEH	36	FE + 1'	WMP(SS)	MCH
2	FE + NSD	WMP(SS) + 5'	OEH	37	FE	MCL	SH
3	FE + NSD	WMP(SS) + 1/2 NSD	Floor	38	FE	MCL	MBH
4	FE + NSD	WMP(SS) + 1/2 NSD	OEH	39	FE	MCL	MCH
5	FE + NSD	WMP(SS) + 1/2 NSD	HMP	40	FE + 1'	WMP(OS)	Floor
6	FE + NSD	WMP(SS)	Floor	41	FE + 1'	WMP(OS)	MMH
7	FE + NSD	WMP(SS)	HMP	42	FE + 1'	WMP(OS)	OEH
8	FE + NSD	MCL	Floor	43	FE + 1'	WMP(OS)	HMP
9	FE + NSD	MCL	HMP	44	FE + 1'	WMP(OS)	SH
10	FE + NSD	WMP(OS)	Floor	45	FE + 1'	WMP(OS)	MBH
11	FE + NSD	WMP(OS)	HMP	46	FE + 1'	WMP(OS)	MCH
12	FE + NSD	WMP(OS) + 1/2 NSD	Floor	47	FE + 1'	WMP(OS) + 1/2 NSD	Floor
13	FE + NSD	WMP(OS) + 1/2 NSD	OEH	48	FE + 1'	WMP(OS) + 1/2 NSD	OEH
14	FE + NSD	WMP(OS) + 1/2 NSD	HMP	49	FE + 1'	WMP(OS) + 1/2 NSD	HMP
15	FE + 1/2 NSD	WMP(OS) + 1/2 NSD	Floor	50	OH + 5'	MCL	SH
16	FE + 1/2 NSD	WMP(OS) + 1/2 NSD	OEH	51	OH + 3'	WMP(SS) + 3'	Floor
17	FE + 1/2 NSD	WMP(OS) + 1/2 NSD	HMP	52	OH + 3'	WMP(SS) + 3'	OEH
18	FE + 1/2 NSD	WMP(OS) + 1'	Floor	53	OH + 3'	WMP(SS) + 3'	HMP
19	FE + 1/2 NSD	WMP(OS) + 1'	HMP	54	OH + 1/2 NSD	WMP(SS) + 1/2 NSD	OEH
20	FE + 1/2 NSD	WMP(SS) + 1'	Floor	55	OH	WMP(SS) + 5'	OEH
21	FE + 1/2 NSD	WMP(SS) + 1'	HMP	56	OH - 3'	WMP(SS) + 5'	OEH
22	FE + 1/2 NSD	WMP(SS) + 1/2 NSD	Floor	57	RE (w/MBS(SS))	MBS(SS)	MMH
23	FE + 1/2 NSD	WMP(SS) + 1/2 NSD	HMP	58	RE (w/MBS(SS))	MBS(SS)	MBH
24	FE + 2'	WMP(SS) + 1/2 NSD	Floor	59	RE (Midline)	WMP(SS) + 4'	MMH
25	FE + 2'	WMP(SS) + 1/2 NSD	OEH	60	RE (Midline)	WMP(SS) + 4'	OEH
26	FE + 2'	WMP(SS) + 1/2 NSD	HMP	61	RE - 1/2 NSD	WMP(SS) + 4'	OEH
27	FE - 3'	WMP(SS) + 2'	Floor	62	RE - 1/2 NSD	WMP(SS) + 4'	MBH
28	FE - 3'	WMP(SS) + 2'	OEH	63	RE (Midline)	MCL	MMH
29	FE - 3'	WMP(SS) + 2'	HMP	64	RE (Midline)	MCL	MBH
30	FE + 1'	WMP(SS)	Floor	65	RE (w/MBS(OS))	MBS(OS)	MMH
31	FE + 1'	WMP(SS)	MMH	66	RE (w/MBS(OS))	MBS(OS)	MBH
32	FE + 1'	WMP(SS)	OEH	67	RE - 1/2 NSD	WMP(OS) + 4'	OEH
33	FE + 1'	WMP(SS)	HMP	68	RE - 1/2 NSD	WMP(OS) + 4'	MBH
34	FE + 1'	WMP(SS)	SH	69	RE (Midline)	WMP(OS) + 5'	MMH
35	FE + 1'	WMP(SS)	MBH	70	RE (Midline)	WMP(OS) + 5'	OEH
				71	OH - 4'	WMP(OS) + 5'	OEH

Table 5.3. Recommended Visual Attention Locations for Scoop Operations

No.	Fore-Aft	Side-to-Side	Up-Down	No.	Fore-Aft	Side-to-Side	Up-Down
1	FE + NSD	WMP(OS) + 1/2 NSD	Floor	28	FE + 1/2 NSD	WMP(OS) + 1/2 NSD	Floor
2	FE + NSD	WMP(OS) + 1/2 NSD	OEH	29	FE + 1/2 NSD	WMP(OS) + 1/2 NSD	HMP
3	FE + NSD	WMP(OS) + 1/2 NSD	HMP	30	FE + 2'	WMP(OS) + 1/2 NSD	Floor
4	FE + NSD	WMP(OS)	Floor	31	FE + 2'	WMP(OS) + 1/2 NSD	HMP
5	FE + NSD	WMP(OS)	OEH	32	FE	WMP(OS) + 5'	Floor
6	FE + NSD	WMP(OS)	HMP	33	FE	WMP(OS) + 5'	HMP
7	FE + NSD	MCL	Floor	34	FE + 1'	WMP(OS) + 1'	Floor
8	FE + NSD	MCL	OEH	35	FE + 1'	WMP(OS) + 1'	MMH
9	FE + NSD	MCL	HMP	36	FE + 1'	WMP(OS) + 1'	HMP
10	FE + NSD	OCL	HMP	37	FE	MCL	MMH
11	FE + NSD	WMP(SS)	Floor	38	FE	WMP(SS)	MMH
12	FE + NSD	WMP(SS)	OEH	39	FE	WMP(SS)	HMP
13	FE + NSD	WMP(SS)	HMP	40	FE + 1'	WMP(SS) + 3'	Floor
14	FE + NSD	WMP(SS) + 5'	Floor	41	FE + 1'	WMP(SS) + 3'	MMH
15	FE + NSD	WMP(SS) + 5'	HMP	42	FE + 1'	WMP(SS) + 3'	OEH
16	FE + NSD	WMP(SS) + 1/2 NSD	Floor	43	FE + 1'	WMP(SS) + 3'	HMP
17	FE + NSD	WMP(SS) + 1/2 NSD	OEH	44	FE + 2'	WMP(SS) + 1/2 NSD	Floor
18	FE + NSD	WMP(SS) + 1/2 NSD	HMP	45	FE + 2'	WMP(SS) + 1/2 NSD	HMP
19	FE + 1/2 NSD	WMP(SS) + 1/2 NSD	Floor	46	OH + 5'	WMP(SS)	MMH
20	FE + 1/2 NSD	WMP(SS) + 1/2 NSD	HMP	47	OH + 5'	WMP(SS)	SH
21	FE + 1/2 NSD	WMP(SS) + 3'	Floor	48	RE	WMP(SS) + 1'	MMH
22	FE + 1/2 NSD	WMP(SS) + 3'	HMP	49	RE	WMP(SS) + 1'	HMP
23	FE + 1/2 NSD	OCL	Floor	50	RE - 5'	WMP(SS) + 5'	Floor
24	FE + 1/2 NSD	OCL	SH	51	RE - 5'	WMP(OS) + 5'	Floor
25	FE + 1/2 NSD	MCL	SH	52	RE	WMP(OS) + 5'	HMP
26	FE + 1/2 NSD	WMP(OS) + 2'	Floor	53	RE	WMP(OS)	MMH
27	FE + 1/2 NSD	WMP(OS) + 2'	HMP	54	RE	WMP(OS)	HMP

Figure 5.7. Pattern of visual attention locations (fore-aft and lateral) for shuttle car operation. Numbers refer to Table 5.1.

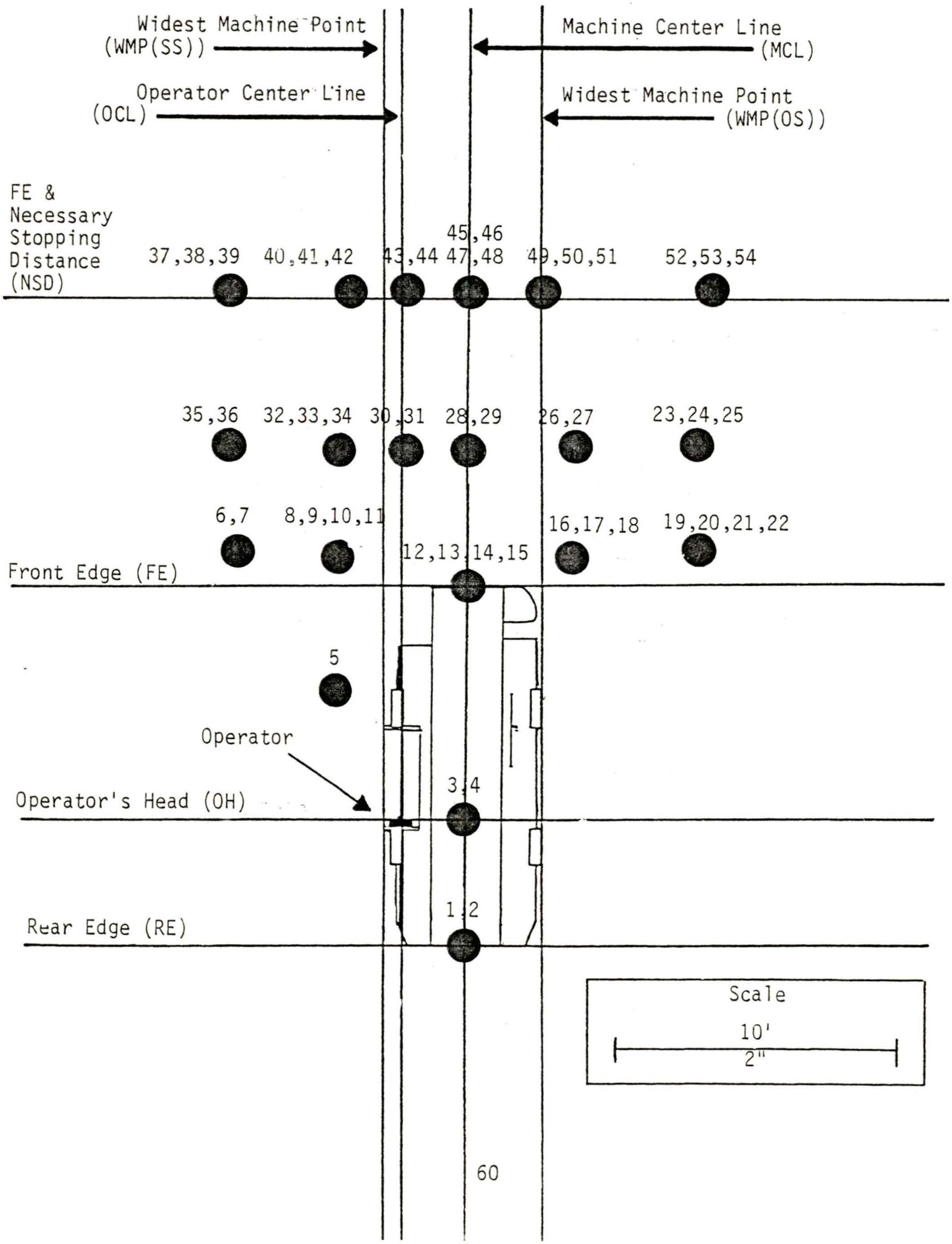


Figure 5.8. Pattern of visual attention locations (fore-aft and lateral) for continuous miner operation. Numbers refer to Table 5.2.

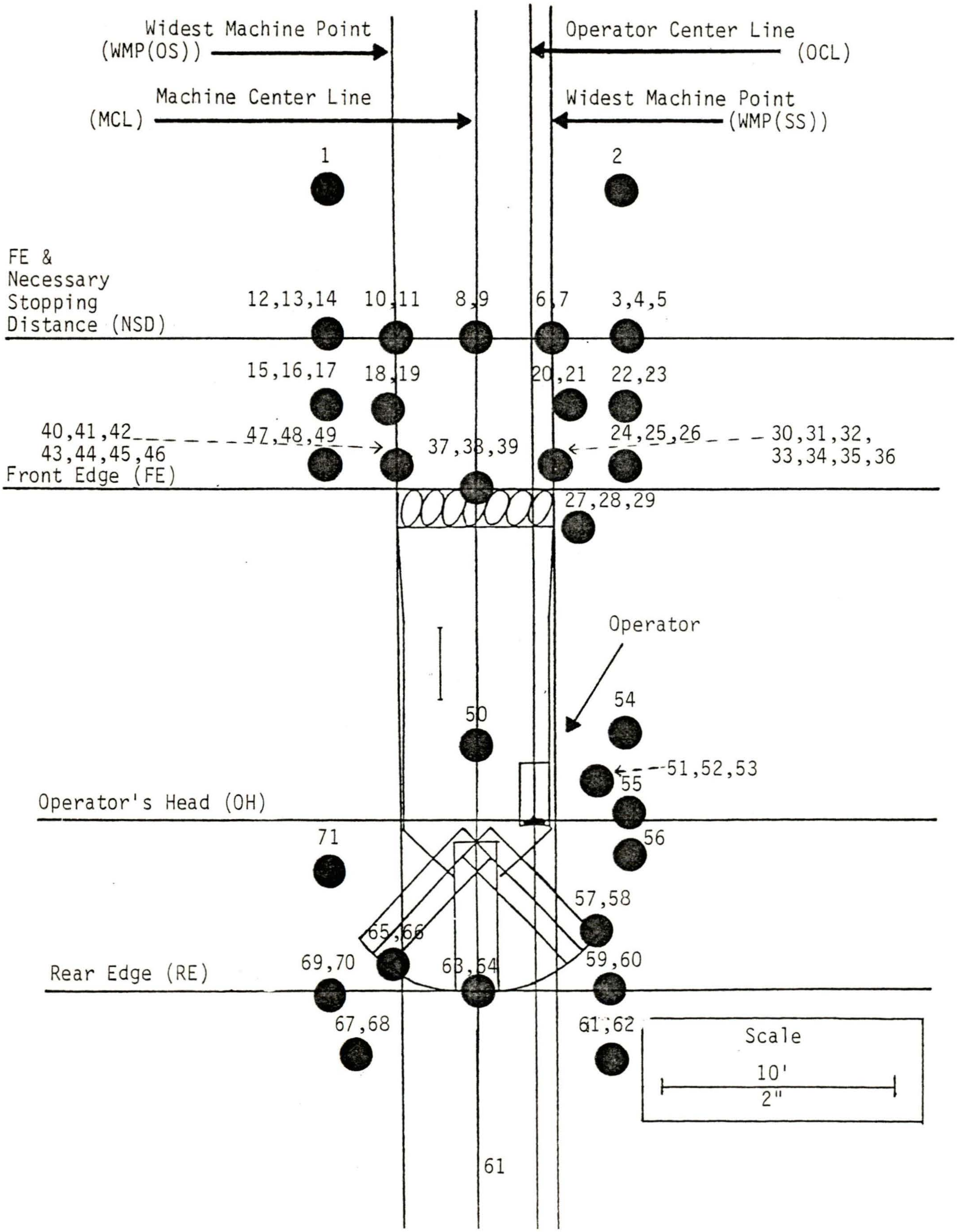
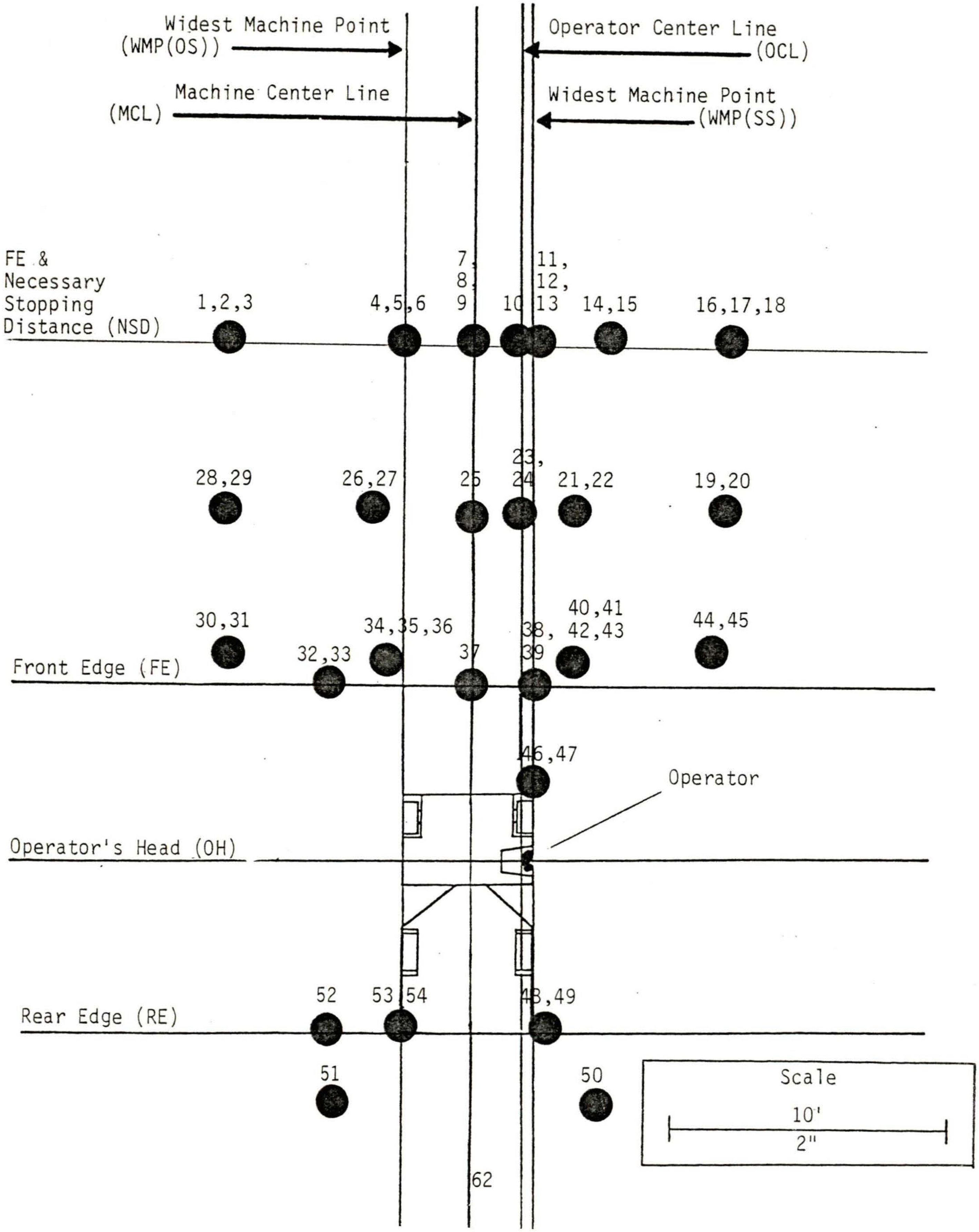


Figure 5.9. Pattern of visual attention locations (fore-aft and lateral) for scoop operation. Numbers refer to Table 5.3.



Translated, this VAL is located 20 ft. (the necessary stopping distance) from the front edge of the car at the operator center line and at the medium machine height. In this case, the operator needs to see the VAL because 20 ft. is the minimum distance in which an obstruction would need to be seen in order to avoid a collision with the obstruction and the upper front edge of the shuttle car (which is the MMH).

Mark the pattern of VALs for the machine being investigated on the floor using a tape measure and chalk stick. It is only necessary to place a mark on the floor corresponding to every unique set of fore-aft and side-to-side locations as listed in Tables 5.1, 5.2, and 5.3.

Shuttle cars tram in two directions which requires that the HERMI procedure be repeated for both the inby and outby ends of the car. Shuttle cars, however, often have the operator's cabs located on the side at the center of the car. When the configuration of the car is approximately the same fore and aft, the procedure may be performed for only the outby end of the car. The outby end is the most important to investigate because the car is loaded when it trams away from the face.

5.7 Step 6. Measure Visibility

Visibility is measured by examining HERMI from each of the visual attention locations. The out-side-in technique is based on the rational that if any part of the HERMI eye arcs can be seen from a VAL then an operator using a reasonable amount of neck and trunk flexion could see the VAL. Determining whether or not any part of HERMI can be seen may be accomplished several ways. Experience has shown that using a sight tube or camera provides accurate data.

The sight tube is a 4 in. (10 cm) tube with a 1 in. (2.5 cm) inside diameter mounted on a camera tripod. The tripod can be set at the up-down position of the VAL. By aiming and looking through the tube at the operator's cab it is possible to determine whether or not HERMI can be seen.

It is recommended that a 35mm camera be used to take black and white photographs at each VAL. Several additional recommendations are:

	RECOMMENDATIONS	RATIONALE
1.	Use a 100mm telephoto lens for all photographs.	HERMI can be seen clearly at a distance. Maintains a consistent perspective of size and distance.
2.	Place a 60 watt flood lamp in the cab.	Illuminates the HERMI eye arcs.
3.	Include 4 x 5 in. black and white cards with the VAL number in each photograph.	The cards will help identify each photograph.
4.	Use 400 ASA black and white film.	Provides high contrast and a good range of exposures.

RECOMMENDATIONS	RATIONALE
5. Print oversized proof sheets (2 x 2 1/2 in.).	Inexpensive. Provides an easy-to-see image.

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