NBSIR 77-1299

POWER LAWN MOWERS: Time-to-Blade Access

A. M. Ramey
J. J. Persenky

Human Factors Section
Product Systems Analysis Division
Center for Consumer Product Technology
Institute for Applied Technology
National Bureau of Standards

May 1977

Final Report

Prepared for
U.S. Consumer Product Safety Commission

NBSIR 77-1299

POWER LAWN MOWERS: TIME-TO-BLADE ACCESS

A. M. Ramey
J. J. Persensky

Human Factors Section
Product Systems Analysis Division
Center for Consumer Product Technology
Institute for Applied Technology
National Bureau of Standards

May 1977

Final Report

Prepared for
U.S. Consumer Product Safety Commission

U.S. DEPARTMENT OF COMMERCE, Juanita M. Kreps, *Secretary*

Dr. Sidney Harman, *Under Secretary*

Jordan J. Baruch, *Assistant Secretary for Science and Technology*

NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Acting Director*

Table of Contents

List of Figures

List of Tables

Acknowledgements

The authors wish to acknowledge the help of Michael Fulcomer, Harry Appleby, and James Huckeba in instrument construction, Barbara Stanton and Addie Stewart in data collection, and Kim Leaman and Bonnie Matteson in secretarial support.

ABSTRACT

This document is the final report for the Consumer Product Safety Commission of an investigation of time-to-blade access for walk-behind power mowers. The problem studied was: "How long after the dead-man control is released should a lawn mower blade be allowed to rotate?" The Human Factors Section at NBS performed this empirical study of operator movement time to determine an ergonomically sound recommendation for blade stopping time.

One hundred participants were tested using a reaction time device designed to measure mower users' approach times to various areas of potential blade contact. The test apparatus permitted measurement of both reaction time--or time to release a simulated dead-man control at the onset of a cue light and, more importantly, movement time--or the time from the release of the dead-man control to activation of one of five switches in the blade access area.

Analysis of the data revealed no statistically significant differences in reaction time as a function of movement distance. As expected, however, movement time does increase linearly as movement distance increases. The range of average movement times observed was from 0.6 to 3.3 seconds. The median movement time at the shortest and longest distances were 1.4 and 2.2 seconds respectively. An inspection of percentile information for movement time suggests a blade-stopping time of 0.7 seconds in order to protect the maximum reasonable number of people.

Recommendations for needed further research are discussed.

Power Lawn Mowers:
Time-to-Blade-Access

1.0 Introduction

The Product Profile, "Power Mowers" prepared by the U.S. Consumer Product Safety Commission (CPSC) and dated October 1976 (1), indicates that there were an estimated 178 000 power mower-related injuries in 1975. The associated costs were estimated to be in excess of 73 million dollars. The National Electronic Injury Surveillance System estimates that over half of these injuries are from contact with the blade. In an attempt to reduce the number of blade contact injuries, the CPSC has accepted Consumers Union's (CU) proposal (under Section 7 of the Consumer Product Safety Act) to include a requirement for a dead-man control on power lawn mowers. This dead-man control must be continuously activated by the lawn mower operator in order for the blade to operate. If the control is released, the blade must stop.

The problem raised by this requirement is: "How long after the dead-man control is released should the blade be allowed to rotate?" An alternative question is: "How long does it take an operator to move from the handle location to an area of potential contact with a moving blade?" Several blade stopping times have been suggested. The power mower industry, through the Outdoor Power Equipment Institute, suggested a stopping time of seven seconds (2). Consumers Union suggested a three or four second stopping time based on a brief study of college students using mowers. (3). In December 1974, the National Bureau of Standards (NBS) analyzed data from the University of Iowa and recommended a blade stopping time of one second as a safest case (4).

In view of the inconsistencies among these recommendations, the Office of the Medical Director at CPSC requested that the NBS Human Factors Section perform an empirical study of operator movement time to determine an ergonomically sound recommendation for blade stopping time for walk-behind power mowers.

This report describes the results of Phase I of a proposed three-phase effort. It is anticipated that Phase II will be designed to determine how operators approach the blade area in a naturalistic setting. Phase III will then make use of the information collected in Phase II so that a high fidelity simulation of the approach-to-blade area can be designed for laboratory measurement of time-to-blade access.

The current study (Phase I) was a basic laboratory simulation of operator approach-to-blade-area patterns where the data were time-to-blade-area access. The 100 participants were tested using a reaction time device designed to simulate a power lawn mower (Figure 1). Both simple reaction time (time from cue activation to release of the lever simulating a dead-man control) and movement time (time from lever release to reaching various lawn mower blade-access areas) were measured.

2.0 Methodology

2.1 Participants

Sixty-four males and 36 females participated in the study. They ranged in age from 16 to 62 years with a mean age of approximately 35 years (S.D. = 12.25 years). Mean height was 174.0 cm (S.D. = 8.7 cm), with a range of 154.6 to 191.3 cm. Weight averaged 72.3 kg (S.D. = 15.8 kg), with a range of 45.9 kg to 138.6 kg. Of the participants 88 were right hand preferred and 12 were left hand preferred.

2.2 Apparatus

A sketch of the simulator used in this study is presented in Figure 2. The test apparatus included: a dead-man control located at the handle, five location-indicator lights and corresponding switches, and a cue light. All parts were mounted on a plywood platform equipped with wheels for ease of transport.

Five switches were positioned behind metal plates on the right side of the apparatus at distances which represented areas of potential blade contact. Distance data were collected from a sample of typical lawn mowers and included the horizontal distance from the handle to the right rear wheels, discharge chutes, and right front wheels. The closest back wheel was found to be 50.0 cm from the handle, whereas the farthest front wheel was 150.0 cm. Switches One through Five on the test fixture were situated at 50.0, 75.0, 100.0, 125.0, and 150.0 cm from the handle, respectively. Five orange location-indicator lights were positioned along the top of the right side of the platform at distances corresponding to the switch locations.

A red cue light was located at the far end of the platform, 180.0 cm from the handle. This light cued the participants to release the handle and move to and depress the switch corresponding to the orange light which was lit.

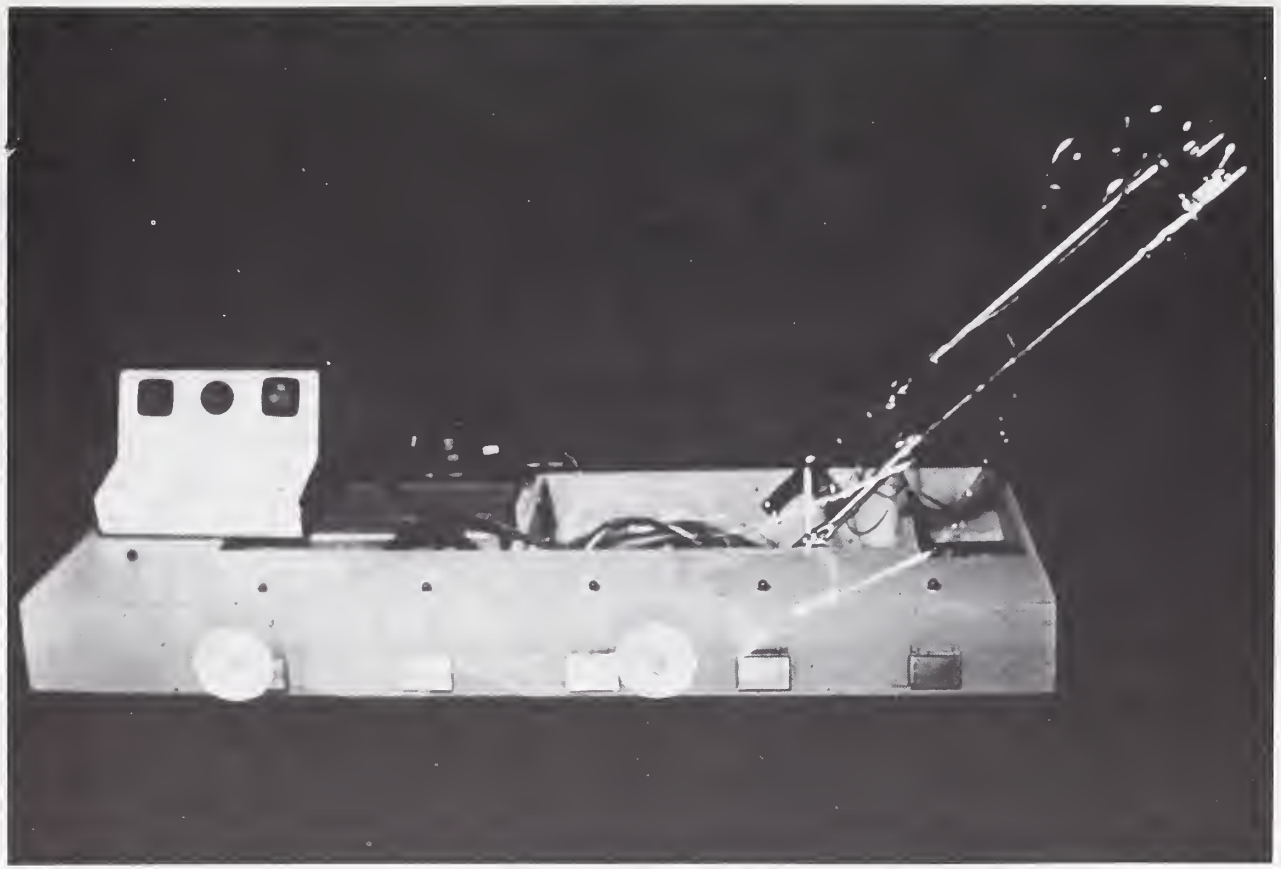


Figure 1. Comparison of Lawn Mower to Simulator

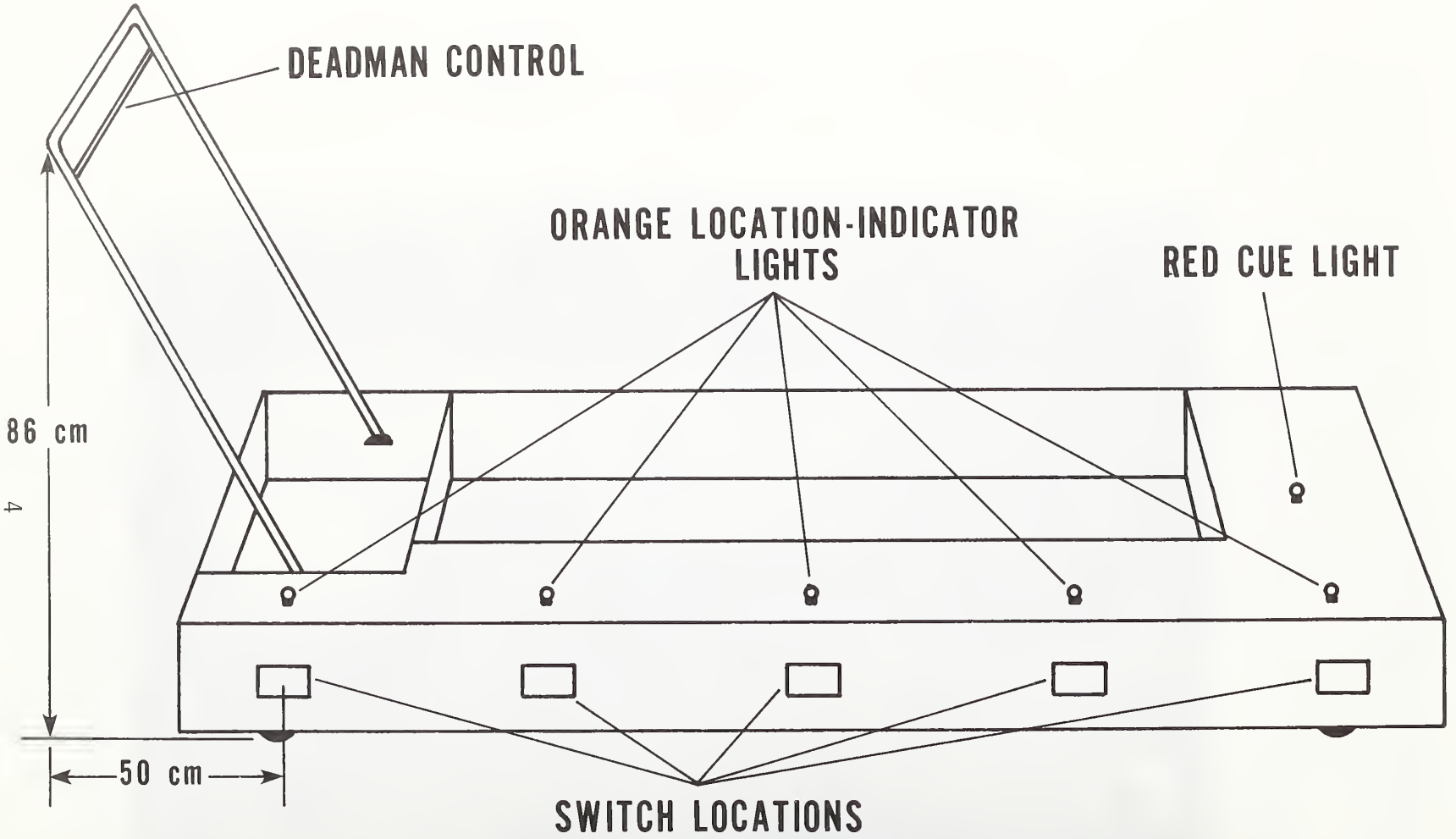


Figure 2. Test Fixture

The control box included three timers and switches for activating the various location-indicator and cue lights. The timers measured:

T_1 - Simple Reaction Time; that is, time between cue light presentation and handle release.

T_2 - Movement Time discounting errors; that is, time from handle release to striking any of the switches.

T_3 - Movement Time to correct switch; that is, time from handle release to striking the correct switch.

Reaction times were recorded to 0.1 of a second. Timer T_1 was activated by the experimenter and timers T_2 and T_3 were activated by the release of the dead-man control.

In addition to the three timers and the light controls, the experimenter operated a separate timer to set the inter-trial (time between complete trials) and inter-stimulus (time between onset of location-indicator light and cue light) intervals.

The wiring diagram for the test fixture is presented in Appendix A.

2.3 Procedure

Once the required consent form was signed, each participant's age, sex, weight, height, and handedness were recorded.

Participants were then instructed to:

- Stand behind the handle.
- Grip the dead-man control when a location-indicator light was activated.
- When the cue light was activated, release the handle, move to and depress the switch corresponding to the location-indicator light.
- Return to the original position behind the panel and await the next trial.

In addition the participants were instructed to move at a normal rate of speed and not to rush.

The total number of trials per participant was 25, five trials at each of the five positions. The presentation sequence was randomized for each subject.

The inter-trial interval was held constant at 15 seconds. However, the inter-stimulus interval varied from 5 to 15 seconds with a mean of 10 seconds. The time between presentation of the location-indicator lights and the cue light was randomized.

A copy of the consent form, instructions, and data sheet are included in Appendix B.

3.0 Results

Blade-area-access-time data are summarized in Table 1. Simple reaction time (T_1) and movement time to correct switch (T_3) are presented separately, as are data for left- and right-handed participants. In addition, data for all participants, combining left- and right-handed individuals, are presented. Time for errors (T_2) is not presented since only one error was committed in the 2500 trials.

No mean difference (t-test) was found between the left and right-handed group for simple reaction time (T_1). Also, a t-test for independent samples revealed that the differences between the right- and left-handed groups in movement time (T_3) were not significant[1]. Therefore, data for both groups were combined for further analysis.

A Treatment by Subjects Analysis of Variance was performed for reaction time (T_1). No significant treatment effect was found[2]. A similar analysis of the movement time (T_3) data yielded a significant treatment effect[3]. A summary of the analysis of variance for movement time is presented in Table 2.

The Duncan Multiple-Range Test was used to further analyze the significant treatment effect found for movement time (See Table 3). The results indicate that a positive relationship exists between distance and movement time. As would be expected, this relationship is an increasing linear function; specifically, for every 25.0 cm that distance increased, movement time increased by 0.2 seconds.

---

[1] ($t(98) = 1.13$, $p > .05$)
[2] [$F(4,396) = 2$, $p > .05$]
[3] [$F(4,396) = 339.16$, $p < .01$]

Table 1

Reaction Time and Time to
Move from Lawn Mower Handle
to Various Locations on the Housing
(Based on Participants' Averages for 5 Trials)

Time	Statistic	Switch Position 50.0 cm Seconds	75.0 cm Seconds	100.0 cm Seconds	125.0 cm Seconds	150.0 cm Seconds
		Right Handed Participants (N = 88)				
Reaction	Med	0.5	0.5	0.6	0.6	0.6
	Range	0.3-1.2	0.3-2.0	0.3-1.1	0.3-1.3	0.3-2.0
Movement	Med	1.4	1.5	1.8	2.0	2.2
	Range	0.6-2.7	0.7-2.8	0.7-3.0	0.8-3.3	0.9-3.8
		Left Handed Participants (N = 12)				
Reaction	Med	0.5	0.6	0.5	0.6	0.6
	Range	0.3-0.9	0.3-0.8	0.3-0.9	0.3-1.1	0.3-1.1
Movement	Med	1.4	1.4	1.6	1.8	1.9
	Range	0.7-2.1	0.6-2.0	0.9-2.1	1.1-2.5	1.2-3.0
		Combined Data (N = 100)				
Reaction	Med	0.5	0.5	0.6	0.6	0.6
	Range	0.3-1.2	0.3-2.0	0.3-1.1	0.3-1.3	0.3-2.0
Movement	Med	1.4	1.5	1.8	2.0	2.2
	Range	0.6-2.7	0.6-2.8	0.7-3.0	0.8-3.3	0.9-3.0

Table 2

Analysis of Variance

Movement Time (T_3)

Source	SS	df	ms	F	p
Total	190.0	499	-----	------	----
Subjects	136.7	99	-----	------	----
Treatments	40.7	4	10.17	339.16	<.01
Error	12.6	396	0.03	------	----

Table 3

Duncan Multiple-Range Test

Movement Time (T_3)

		Position						
		50.0 cm	75.0 cm	100.0 cm	125.0 cm	150.0 cm		
Position	$\bar{X}$	1.4	1.6	1.8	2.0	2.2	r	Critical Range
50.0 cm	1.4	---	.2*	.4*	.6*	.8*	5	.03
75.0 cm	1.6	---	---	.2*	.4*	.6*	4	.03
100.0 cm	1.8	---	---	---	.2*	.4*	3	.02
125.0 cm	2.0	---	---	---	---	.2*	2	.02
150.0 cm	2.2	---	---	---	---	---		

* $p < .05$

4.0 Discussion

The major conclusion of the present study is that a blade stopping time in excess of 2.2 seconds may be too long for a majority of the population. This is based on the 2.2 second median for movement time at the longest distance and the even shorter times for the other distances tested. It is recommended that a "worst case" approach be adopted when establishing a blade stopping time for regulatory purposes. That is to say, the 5th percentile time is recommended, since this is the fastest time that could be achieved. Therefore, a greater percentage of the population, approximately 95 percent of the sample, would be protected if this time were adopted for the regulation. Also, the time selected should be based on position one, the closest position, since some of the mower adjustments which have resulted in accidents have been at this position.

Table 4 presents percentile information for movement time for each of the five simulated blade-contact locations. It can be seen again that if a "worst case" approach is taken, it is the 5th percentile time, rather than the 95th, which would protect 95 percent of the population. Conversely, only five percent of the population would be protected if the 95th percentile time were adopted. It is, of course, CPSC's responsibility to establish the blade-stopping time. As seen in Table 4, solely in terms of basic Movement Time, 0.7 seconds (the 5th percentile time for the closest position) would be the appropriate conservative choice.

In lieu of any data to the contrary, it must be assumed that lawn mower operators move directly from the position behind the mower handle to an area of potential blade contact. For example, they may go immediately from the handle to the wheels to make height adjustments or to discharge chute to remove debris. In the original lawn mower research proposal to CPSC, the NBS proposed to conduct field observations of lawn mower operators so that realistic movement scenarios could be developed (Phase II). Further, these scenarios would then be simulated in a laboratory setting to determine actual movement times. Until these studies are performed, more valid time criteria cannot be determined.

Table 4

Percentile Data

Movement Time (T_3) in Seconds

	Switch Position				
	50.0 cm	75.0 cm	100.0 cm	125.0 cm	150.0 cm
Median	1.4	1.5	1.8	2.0	2.2
5th Percentile	0.7	0.8	0.9	1.1	1.2
95th Percentile	2.2	2.5	2.8	3.0	3.2

References

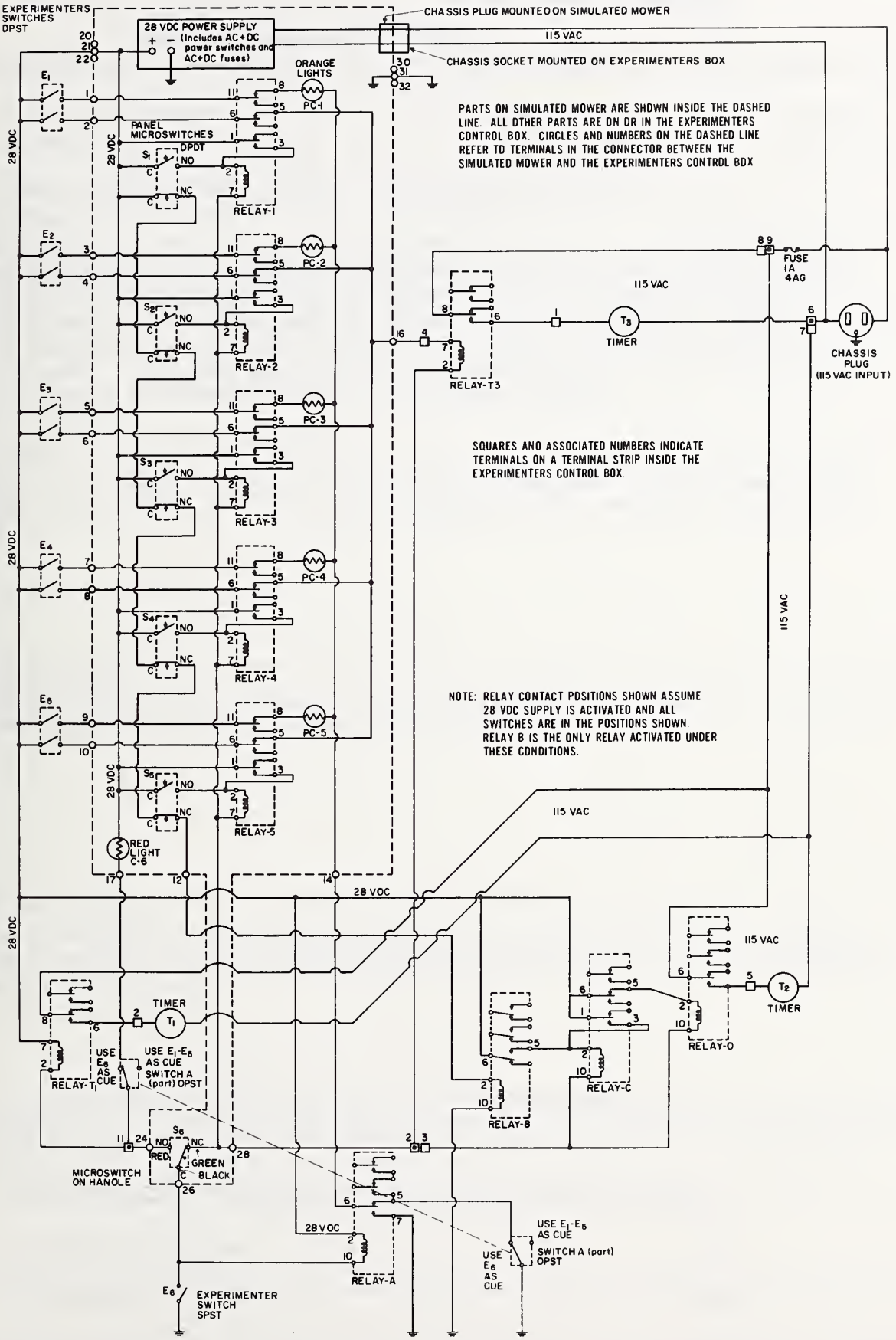
1. U.S. Consumer Product Safety Commission, Product Profiles: Power Mowers, October 1976.

2. Outdoor Power Equipment Institute, Technical Comments and Recommendations on Proposed Lawn Mower Safety Standard, Submitted to the U.S. Consumer Product Safety Commission, September 1975.

3. Consumers Union of United States, Inc., Proposed Safety Standard for Power Lawn Mowers, Submitted to the U.S. Consumer Product Safety Commission, July 1975.

4. Porter, L.G., Jones, C.E., and Persensky, J.J. Some Aspects of Lawn Mower Safety, Status Report to U.S. Consumer Product Safety Commission, December 1974.

Appendix A--Wiring Diagram



APPENDIX B_1

NBS-783
(2-75)

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

3. Cost Center No.

RESEARCH PARTICIPANT AGREEMENT

1. Principal Investigator: Dr. J. J. Persensky

2. Division/Section: 441.02

4. Location: [X] Gaithersburg [ ] Other (specify)

5. Experiment Name/Code: Time to Mower Blade Access. Phase I: Preliminary Simulation

6. Description of Experiment

The purpose of this research is to determine how long it takes a lawn mower operator to move from the handle to different locations on the mower housing. The equipment used is not an actual lawn mower but is designed to simulate actual distances. The participant is asked to stand at the handle until a signal light is presented, then to move to and touch a panel near the front of the simulated mower. This procedure will be repeated several times. The test will help to define safe stopping times for lawn mower blades.

7. Risks to Participant

There is a slight possibility that when moving around the equipment, the participant might fall. To avoid such accidents a slip resistant surface will be used.

8. Responsibilities of Participant

The participant, with informed consent, will follow instructions and answer questions regarding age, sex, weight, and handedness.

9. Responsibilities of Investigator(s)

The investigator will (1) fully explain the test procedure, (2) explain the purpose of the test, (3) provide safe test conditions, and (4) keep personal information confidential.

10. IT IS UNDERSTOOD THAT EITHER THE PRINCIPAL INVESTIGATOR, THE PARTICIPANT, OR THE PARTICIPANT'S PARENT OR GUARDIAN MAY TERMINATE THE PARTICIPANT'S INVOLVEMENT IN THE RESEARCH AT ANY TIME WITHOUT INCURRING LEGAL LIABILITY FOR SUCH TERMINATION.

11. I hereby certify that my participation is voluntary and that I have read and accept the terms of this agreement.

Participant, or Parent or Guardian (Signature) | Date

12. Principal Investigator (Signature) | Date

13. Early Termination by (Signature) | Date

APPENDIX B_2

Instructions

Time-to-Blade-Access

I want you to stand behind this handle. When you see one of the orange lights come on, please grip the handle. Then, when you see the red light at the far end of the box come on, release the handle and depress the metal plate under the orange light that is lit. When you hit the metal plate, the orange light will go out. Then return to the handle area and wait for one of the orange lights to come on again. Please don't hurry to strike the metal plates, but rather walk at a normal rate of speed.

Do you have any questions?

SAMPLE DATA SHEET

TIME TO BLADE ACCESS

TRIAL #	ISI + 15	ISI	PC #	T_1	T_2	T_3
1	24	9	2			
2	24	9	5			
3	23	8	3			
4	30	15	3			
5	20	5	5			
6	22	7	4			
7	30	15	2			
8	25	10	4			
9	24	9	1			
10	28	13	5			
11	22	7	4			
12	20	5	2			
13	23	8	2			
14	29	14	1			
15	26	11	5			
16	29	14	3			
17	23	8	5			
18	27	12	4			
19	26	11	1			
20	26	11	2			
21	22	7	4			
22	30	15	3			
23	28	13	1			
24	27	12	3			
25	25	10	1			

DATE

SUBJECT

HEIGHT

WEIGHT

SEX

AGE

HANDEDNESS

NBS-114A (REV. 7-73)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET	1. PUBLICATION OR REPORT NO. NBSIR 77-1299	2. Gov't Accession No.	3. Recipient's Accession No.

4. TITLE AND SUBTITLE

Power Lawn Mowers: Time-to-Blade-Access

5. Publication Date May 1977

6. Performing Organization Code

7. AUTHOR(S)

A. M. Ramey, J. J. Persensky

8. Performing Organ. Report No.

9. PERFORMING ORGANIZATION NAME AND ADDRESS

NATIONAL BUREAU OF STANDARDS
DEPARTMENT OF COMMERCE
WASHINGTON, D.C. 20234

10. Project/Task/Work Unit No. 441-1424

11. Contract/Grant No.

12. Sponsoring Organization Name and Complete Address (Street, City, State, ZIP)

Consumer Product Safety Commission
5401 Westbard Avenue
Washington, D. C. 20207

13. Type of Report & Period Covered Final

14. Sponsoring Agency Code

15. SUPPLEMENTARY NOTES

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

This document is the final report for the Consumer Product Safety Commission of an investigation of time-to-blade access for walk-behind power mowers. The problem studied was: "How long after the dead-man control is released should a lawn mower blade be allowed to rotate?" The Human Factors Section at NBS performed this empirical study of operator movement time to determine an ergonomically sound recommendation for blade stopping time.

One hundred participants were tested using a reaction time device designed to measure mower users' approach times to various areas of potential blade contact. The test apparatus permitted measurement of both reaction time--or time to release a simulated dead-man control at the onset of a cue light and, more importantly, movement time--or the time from the release of the dead-man control to activation of one of five switches in the blade access area.

Analysis of the data reveal no statistically significant differences in reaction time as a function of movement distance. As expected, however, movement time does increase linearly as movement distance increases. The range of average movement times observed was from 0.6 to 3.3 seconds. The median movement time at the shortest and longest distances were 1.4 and 2.2 seconds respectively. An inspection of percentile information for movement time suggests a blade-stopping time of 0.7 seconds in order to protect the maximum number of people.

Recommendations for needed further research are discussed.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Consumer product; human factors; lawn mowers; reaction time; safety; standards

18. AVAILABILITY

[X] Unlimited

[ ] For Official Distribution. Do Not Release to NTIS

[ ] Order From Sup. of Doc., U.S. Government Printing Office Washington, D.C. 20402, SD Cat. No. C13

[ ] Order From National Technical Information Service (NTIS) Springfield, Virginia 22151

19. SECURITY CLASS (THIS REPORT) UNCLASSIFIED

21. NO. OF PAGES 20

20. SECURITY CLASS (THIS PAGE) UNCLASSIFIED

22. Price