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STATE OF CALIFORNIA
BUSINESS AND TRANSPORTATION AGENCY
DEPARTMENT OF PUBLIC WORKS

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A

STUDY OF THE EFFECTS

OF GROOVING ON

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72-69

HOUSE RESOLUTION NO. 126
1971 REGULAR SESSION

January 1972

72-69

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STATE OF CALIFORNIA—TRANSPORTATION AGENCY

RONALD REAGAN, Governor

DEPARTMENT OF PUBLIC WORKS
1120 N STREET
SACRAMENTO, CALIFORNIA 95814

January 26, 1972

Honorable James D. Driscoll
Chief Clerk of the Assembly
State Capitol

Dear Mr. Driscoll:

House Resolution No. 126 of the 1971 Regular Session by Assemblyman Eugene Chappie requested the Department of Public Works to conduct and submit the results of a study on rain grooves in highways with respect to their effect on motor vehicle accidents, particularly motorcycles and other two-wheeled vehicles to the Legislature prior to February 5, 1972.

Two copies of a report on the results of that study are attached.

Respectfully,

JAMES A. MOE
Director of Public Works

Enclosure

cc: Honorable Darryl R. White
Secretary of the Senate

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READ AND ADOPTED 10/1/71

By Assemblyman Chappie:

House Resolution No. 126

Relative to rain grooves in highways

Resolved by the Assembly of the State of California, That the Members hereby request the Department of Public Works to conduct a study of rain grooves in highways with respect to their effect on motor vehicle accidents, particularly motorcycles and other two-wheeled motor vehicles; and be it further

Resolved, That the Department of Public Works submit its findings and recommendations to the Legislature not later than February 5, 1972; and be it further

Resolved, That the Chief Clerk of the Assembly transmit a copy of this resolution to the Director of Public Works.

Resolution read, and referred by the Speaker pro Tempore to the Committee on Rules.

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APPENDIX:

A. Highway Research Report, "Effect of Pavement Grooving on Motorcycle Rideability", California Division of Highways, Materials and Research Department, November 1969.

B. California Department of Public Works Standard Special Provision 40.10, "Groove Existing Concrete Pavement", dated 1-4-71.

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SUMMARY

Grooving has proved to be one of the most cost-effective safety programs of the Department of Public Works. Grooving has contributed greatly to savings in lives, injuries and dollars for the travelling public. Rainfall is comparatively moderate in California but the accident rate is four times greater on wet pavement than on dry pavement. This is one of the problem areas for which a positive solution has been found.

The Department of Public Works' accident experience reveals that grooving has yielded a:

1) 20 percent reduction in total accidents
2) 50 percent reduction in fatal accidents
3) 70 percent reduction in wet pavement accidents

Motorcycle accident reports were reviewed from both grooved and ungrooved sections. Abstracts of these reports are given in the following pages. They show little evidence that grooves constitute a hazard to the cyclist.

The effect of grooving on motorcycle rideability was evaluated in 1966, 1968 and again in 1969. The evaluations were conducted in cooperation with the California Highway Patrol and the Los Angeles Police Department. Their conclusions stated, in general, that: Motorcycles do have different handling characteristics on grooved pavements than on other pavements. The wrong combination of cycle and tires can cause the cyclist to have a "strange feeling". The California Highway Patrol and the motorcycle industry are actively engaged in a program to increase safety, rideability, and control of motorcycles.

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BACKGROUND

In the late 1950's, accident statistics began to reveal that some sections of the older freeways were beginning to have an unusually high number of accidents on wet pavement. Approximately 20,000 (15 percent) of some 129,000 accidents on State highways in 1969 happened on wet pavements. These accidents were typically skidding accidents.

To alleviate the wet pavement problem, the California Division of Highways started grooving pavements in the early 1960's. The grooving program had gained momentum by 1967 with almost 20-lane miles of grooving going to contract that year. Three hundred and ninety lane miles went to contract during the first seven months of 1971. More than 750-lane miles of California State highways have been grooved to date.

Grooves in pavement accomplish two functions. First, the grooves provide an escape path for water. This, in turn, prevents the build-up of a film of water between the tires and road surface that can cause hydroplaning. Secondly, the grooves are like "mini-railroad tracks" that provide tracking for a vehicle. In essence, grooving puts the tread into the road surface that SHOULD have been on the tire in the first place. Bald and worn tires are noted too often on wet pavement accident reports.

GROOVE PATTERNS

About nine different patterns of grooves have been cut, but the most common patterns of existing grooves were cut with 1/8-inch

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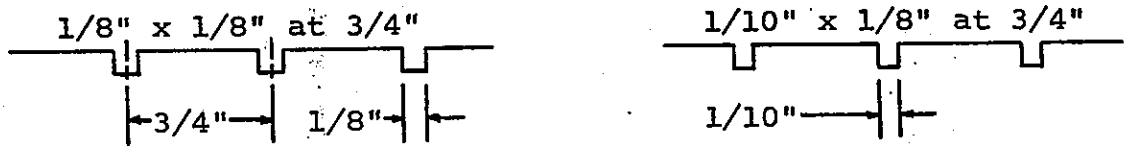
or 1/10-inch wide diamond tipped blades spaced at 3/4-inch centers. Existing specifications (subsequent to 1969) require a groove width of 1/10". (See Appendix B)



MOTORCYCLE RIDEABILITY

As grooving became more common, complaints were received from motorcycle and small car drivers. Their complaint was that grooves affected the handling characteristics of their vehicles.

Three separate dynamic tests were conducted to determine the effect of grooves on motorcycles. The results of the most recent series of tests are presented in Appendix A, "Effect of Pavement Grooving on Motorcycle Rideability" (November 1969).

The two earlier tests (1966 and 1968) indicated that narrower grooves were best. The test drivers in the 1968 test felt they had better stability at 60-80 MPH over the presently specified 1/10-inch wide grooves than over smooth surfaced streets.

The handling characteristics of lighter motorcycles were affected by wider grooves but neither the Los Angeles Police Department nor the California Highway Patrol felt there was a loss of control. Cycles equipped with knobby (off-road) tires were much more sensitive to the grooves. California Highway Patrol cycles are equipped with street-type tires and are not affected by grooving.

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On wet grooved pavement, stopping characteristics of motorcycles were definitely better than on wet ungrooved pavement. Ordinarily, a motorcycle will swing sideways and go down when braked on a wet pavement. In the 1966 test, the test cycle not only stayed up when heavily braked on wet, grooved pavement, but skidded in a straight line with the grooves.

ACCIDENT EXPERIENCE

A large scale study of wet pavement accidents was completed in October 1971. That statewide study included 34-lane miles of grooved pavement and represented 39 locations. The accidents of two years prior were compared to the accidents of two years after grooving.

There were 20 percent fewer accidents in the after period despite a 17 percent increase in traffic. There were 1,133 accidents before grooving and 904 accidents after grooving. Grooving proved most effective as a wet pavement accident deterrent. There were 535 wet pavement accidents before grooving, and 158 after grooving.

The number of fatal accidents was cut in half. There were 21 fatal accidents in the before period; only 10 fatal accidents in the after period. The number of injury accidents dropped from 437 before to 326 after grooving.

Motorcycle accidents were looked at independently. At the 39 locations in the study, there were four accidents in the two-year period before grooving and 11 accidents during the two-year

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period after grooving. During those same four years, fatal and injury motorcycle accidents in California rose from 12,687 to 15,271 annually.

For statistical "control", motorcycle accidents during the after period were tabulated on equal lengths of ungrooved pavement adjacent to the grooved sections. By coincidence, there were 11 accidents on the ungrooved control sections also.

Although 11 accidents in two years is such a small sample that no statistical conclusions can be inferred, the circumstances of the 11 accidents on grooved sections and the 11 accidents on ungrooved adjacent sections are tabulated below:

A. Sections with Grooved Pavement

1. Engine had been erratic as he travelled along at 40 MPH. Accelerated rapidly to 60 MPH in an attempt to clear it up but developed a wobble and lost control.

2. Motorcycle driving 55 MPH on shoulder struck parked car more than two feet from edge of travelled way. Driver claimed he shifted to shoulder because of grooves on travelled way. Bike equipped with ribbed tires.

3. Traffic had queued up due to an accident. Driver of car approaching queue panicked and slammed brakes hard. He bounced off guardrailing and partially blocked lane of cyclist. Cyclist could not avoid collision.

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4. Traffic was queued up and stopped. Pickup ran into rear of stopped motorcycle when pickup's brakes failed. Pickup travelling at 5 MPH.

5. Driver was coming into a curve at 65 MPH in outside lane. Developed wobble, lost control and hit guard-railing.

6. Cyclist (BA=0.12) made wide swing to pass car (possibly hit a hub cap in #1 lane) and lost control. Struck median barrier and was ejected into path of auto.

7. Cycle travelling at 65 MPH when it suddenly developed a wobble. Bike went down ejecting both riders. Wobble possibly caused by flat rear tire. No sign of blow-out.

8. Cycle was moving at high speed (est. 77 MPH) when front developed a shimmy.

9. Panel truck came up behind cycle at about 65 MPH and ran into rear of cycle. Cycle was travelling about 55 MPH.

10,11. Accident reports not available on two accidents.

B. Adjacent Sections (Ungrooved Pavement)

1. Cycle had stalled out and was stopped in #3 lane. Approaching vehicle swerved to miss and caught cycle with his trailer.

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2. Pavement was wet, vehicles were moving along about 30-40 MPH. Car in #1 lane changed to lane #2 occupied by cycle. Cycle bounced off right side of car and into rear of car in lane #3.

3. Rear tire of cycle blew out and control lost. (Abbreviated report)

4. Cycle developed wobble. When driver accelerated to get rid of wobble, chain broke and cycle went out of control. 40 MPH speed.

5. Cycle apparently overtaken by auto travelling 60 MPH. (Abbreviated report)

6. Two cycles parked on shoulder were waiting to return into traffic. Vehicle came up fast on slow car and veered to right to miss slower car. Hit both cycles.

7. Officer had red light on and was pulling woman driver over for traffic violation. She braked too fast (skidding 40') for officer to stay behind her so he attempted to go around, hit car anyway and skidded.

8. Cycle had switched to shoulder (still moving) and then decided to return to lanes. Hit piece of tread from tire and lost control.

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9. Cycle hit stalled car in #1 lane, then left scene.

10. Pickup overran cycle and then left scene. (Summary report only)

11. Accident report not available on one accident.

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A P P E N D I X

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APPENDIX A

HIGHWAY RESEARCH REPORT

EFFECT OF PAVEMENT GROOVING ON MOTORCYCLE RIDEABILITY

INTERIM REPORT

STATE OF CALIFORNIA

BUSINESS AND TRANSPORTATION AGENCY

DEPARTMENT OF PUBLIC WORKS

DIVISION OF HIGHWAYS

MATERIALS AND RESEARCH DEPARTMENT

RESEARCH REPORT

NO. M & R 633126-6

Prepared in Cooperation with the U.S. Department of Transportation, Bureau of Public Roads November 1969

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STATE OF CALIFORNIA—TRANSPORTATION AGENCY

RONALD REAGAN, Governor

DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
MATERIALS AND RESEARCH DEPARTMENT
5900 FOLSOM BLVD., SACRAMENTO 95819

November, 1969
Interim Report
M&R No. 633126-6

Mr. J. A. Legarra
State Highway Engineer

Dear Sir:

Submitted herewith is a research report titled:

EFFECT OF PAVEMENT GROOVING
ON MOTORCYCLE RIDEABILITY

GEORGE B. SHERMAN
Principal Investigator

JOHN B. SKOG AND
MELVIN H. JOHNSON
Co-Investigators

Assisted by
Gene S. Stucky

Very truly yours,

JOHN L. BEATON
Materials and Research Engineer

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REFERENCE: Sherman, G. B., Skog, J. B. and Johnson, M. H., "Effect of Pavement Grooving on Motorcycle Rideability", State of California, Department of Public Works, Division of Highways, Materials and Research Department, Research Report 633126-6, November, 1969.

ABSTRACT: A study was conducted to determine if the safety of the motorcyclist was impaired by pavement grooving and which pattern of those tested resulted in the least sensation to the cyclist. The six pavement grooving patterns most frequently considered for use on California highways were cut longitudinally into a relinquished PCC section of the State Highway System. Seven motorcycles, ranging from one of the smallest legally allowed on California freeways to one of the largest used, were made available for evaluating these patterns. The evaluation was made by two experienced motorcyclists. The pavement grooving patterns, as tested in this study, did not present a hazardous riding condition to the motorcyclists. In general the lighter machines were more sensitive to the grooving patterns; however, none had a sensitivity level sufficient to cause a control problem. No individual grooving pattern was considered to be consistantly superior, from a motorcycle rideability standpoint.

KEY WORDS: Pavements, grooving, motorcycles, safety, riding quality.

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ACKNOWLEDGMENTS

The authors wish to express their appreciation to the California Highway Patrol, and especially to Mr. Ross Little and Sergeant Larry Piatt, for their cooperation in conducting this study.

The authors wish to thank the County of Yolo for providing the pavement used in this study and the various motorcycle and tire distributors for furnishing the necessary equipment.

This is the sixth in a series of interim reports on a research project dealing with the skid resistance of pavement surfaces. This work was done in cooperation with the U. S. Department of Transportation, Federal Highway Administration, Bureau of Public Roads. The opinions, findings and conclusions expressed in this publication are those of the authors and not necessarily those of the Bureau of Public Roads.

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INTRODUCTION

The advent of extensive pavement grooving in California brought on reports that grooving patterns resulted in riding sensations to the motorcyclist which were different from that experienced on ungrooved pavements. There have been no reports of motorcycle accidents caused by pavement grooving, only indications that certain grooving patterns and/or machines may result in a "strange feeling" to the cyclist.

The effectiveness of pavement grooving in reducing wet weather accidents has been well documented (1,2) and discontinuing its use would create a safety hazard to the majority of the motoring public. Consequently, the logical course of action was to conduct a study to determine to what extent the safety of the motorcyclist was impaired by pavement grooving and which pattern resulted in the least sensation to the cyclist. Therefore, this study was initiated.

The six pavement grooving patterns most frequently considered for use on California highways were cut longitudinally into a relinquished PCC section of the State Highway System near Sacramento. Seven motorcycles, ranging from one of the smallest legally allowed on California freeways to one of the largest used, were made available for evaluating these patterns. The evaluation was made by two experienced motorcyclists. This report discusses the results of the evaluation and is the sixth in a series of reports dealing with skid resistance studies.

CONCLUSIONS

1. In this study, the pavement grooving patterns, when evaluated with the various motorcycles, did not present a hazardous riding condition. In general, the lighter machines were more sensitive to the grooving patterns; however, none had a sensitivity level sufficient to cause a control problem.

2. No individual grooving pattern was considered to be consistently superior, from a motorcycle rideability standpoint.

EVALUATION PROCEDURE

Six patterns were grooved into the test pavement as shown in Figure 1. As can be seen in this figure, 1/8" x 1/8" on 1/2",

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3/4" and 1" centers were tested. One of the test patterns utilized a thinner blade (0.095") at 3/4" centers. Another pattern tested, herein referred to as Style A, consisted of cuts .095" x 1/8" on 3/4" centers with two .095" grooves equally spaced between those on 3/4" centers and not more than 1/16" deep. This particular pattern is used in locations where it is desirable to raise the coefficient of friction of the pavement a significant amount. Christensen Diamond Services Company's Style 15 pattern was also tested. This pattern had previously been reported as one which was superior in increasing the coefficient of friction of smooth pavements (3).

Coefficient of friction determinations were made on the test areas before and after grooving, and the results are shown in Table A. Not much significance, in regard to improving the pavement coefficient of friction, can be noted in these readings, due to the high original values, but they are presented for general information. The test pavement was selected for its overall smooth profile and not for coefficient of friction considerations.

The motorcycles used for the evaluation are shown in Figure 2. The only consideration in the selection of the machines was to encompass the size and weight range normally operated on California freeways. California law requires that a motorcycle must have 15 gross brake horsepower in order to operate on freeways. The 125cc machine used in this evaluation has a 15.2 hp rating and is one of the smallest which would be legally allowed on the freeways. There are machines of approximately this size and weight which do not meet the horsepower requirements and, therefore, would not be on the freeways. The largest and heaviest machine normally used in California is a fully equipped Highway Patrol model. Most of the motorcycles used in this evaluation were relatively new; however, some had had moderate previous usage.

No attempt was made to conduct an extensive evaluation of tire patterns. All of the machines were run with standard equipment street tires. In addition, evaluations were made with the lightest machine equipped with semi-knobby tires on both the front and rear wheels (Figure 3). It is felt that a machine of this weight equipped with that style tire represents a critical evaluation device for the grooving patterns. Evaluation of the patterns was made also by the 250cc and 500cc machines equipped with a full knobby tire on the rear wheel (Figure 4). Here again it is felt that these test conditions were severe from the standpoint of rideability on the patterns. No evaluation was conducted with a machine equipped with a full knobby tire on the front wheel. Separate evaluations were made with the heavy U. S. machine equipped with the new (5.10 x 16) and old style (5.00 x 16) tires used by the California Highway Patrol (Figure 5).

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The evaluation was performed by two experienced motorcyclists. One was a uniformed Highway Patrolman and the other a non-uniformed employee of the California Highway Patrol. These two men were of different weight and body structure. The largest one who weighed approximately 195 pounds, was 30 pounds heavier than the smaller framed man.

The evaluation was made at a 40-50 mph speed range as well as a 50-60 mph range. The motorcycles were brought up to the proper speed prior to entering the grooving patterns. The cyclists entered the patterns parallel to the grooves and directly from an ungrooved portion of the pavement. Immediately after each run, the cyclist made a subjective evaluation of the relative sensitivity of the particular motorcycle to the pattern being tested. This sensitivity was defined as that amount of feeling greater than experienced on the ungrooved pavement. Initially it was intended to have some type of grading sheet, with various factors to be evaluated, for the cyclists to mark. However, it was later decided that it would be more meaningful for the cyclists to make an overall subjective statement as to relative sensitivity. One of the cyclists weaved in and out of the grooving patterns, for their entire lengths, at both speed ranges. The sensitivity to this maneuver was also subjectively evaluated and recorded after each run.

Thought was given to placing grooving patterns on curved sections; however, a curved section of PCC pavement, in good condition, could not be made available for test purposes. In any event it was felt that a combination of the straight runs and weaving in and out would give a good initial evaluation of the patterns.

DISCUSSION OF EVALUATION

The subjective evaluations made by the motorcyclists were quantitatively rated in order to make graphical representations (Figures 6 through 18). The plots were obtained by combining the evaluation of the two cyclists. In almost every case, their ratings were the same and therefore it is felt that this combination is justifiable. In cases where sensitivity to weaving in and out was experienced, a definite relative sensitivity to straight runs on the same pattern was also experienced; therefore, this quality is not plotted separately. Generally speaking, there wasn't much sensitivity to weaving in and out of the patterns. The majority of the ratings did not vary with speed and of those that did, as many increased with speed as decreased with speed. In any case there wasn't enough consistancy in the effect of this parameter to justify definite conclusions.

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The 1/8" x 1/8" at 1/2" and 1" centers and the Style A patterns, considering all of the motorcycles used, resulted in the least overall sensation to the cyclists (Figures 6, 7 and 10). The two patterns spaced at 3/4" centers resulted in a greater sensation when evaluated by the lighter machines (Figures 8 and 9). However, there are very few 125cc machines and not many 250cc machines on the highways and therefore more emphasis should be put on the reaction of the heavier machines. The Style 15 resulted in the most sensitivity (Figure 11), but here again it should be emphasized that this is only relative riding comfort and that none of the ratings were at a hazardous level.

Figure 12 shows the difference in ratings obtained with street and semi-knobby tires on the 125cc machine. As can be seen, the semi-knobby tires result in somewhat more sensitivity; however, not significantly or consistently. Figure 13 shows a definite increase in sensitivity when the 250cc machine is equipped with a knobby tire on the rear wheel instead of a street tire. When the 500cc machine is equipped with a knobby tire on the rear wheel, there is more sensitivity on some of the patterns (Figure 14). Generally speaking, using semi-knobby tires on both wheels or a full knobby on the rear wheel will result in a "rougher" ride on grooved pavement. This would be expected to be the case on any type of pavement.

Figure 17 shows that the new style tire, presently used on California Highway Patrol motorcycles, results in a significantly improved ride on the 3/4" spaced patterns. Patterns with this spacing are the most predominate on California freeways. Any official reports that Highway Patrol motorcycles were sensitive to grooving patterns were the result of tests made on 3/4" spaced patterns. Further checking on the reports revealed that they were made prior to the time that the Highway Patrol motorcycles were equipped with the new style tires. It is quite evident that the new style tire, which is somewhat wider (5.10 versus 5.00) and has a different tread pattern than the old style (Figure 5), provides an improvement in rideability of the Highway Patrol and heavy U. S. machines on the majority of grooving patterns.

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2. Farnsworth, E. E., "Pavement Grooving on Highways," Pavement Grooving and Traction Studies NASA SP-5073, 1969, National Aeronautics and Space Administration, Washington, D. C., pp. 411-424.

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Figure 1

GROOVING PATTERN TEST LAYOUT

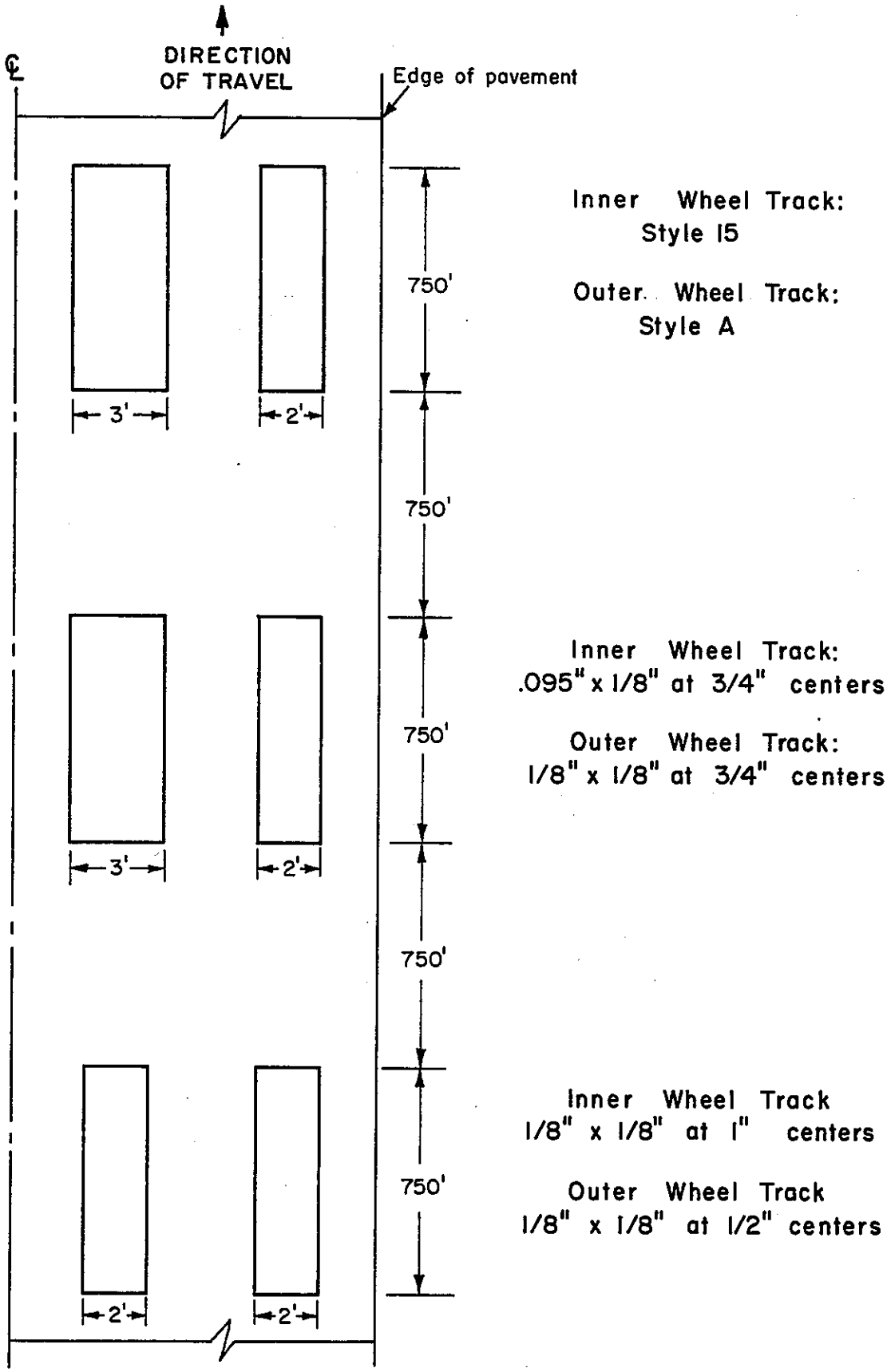

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TABLE A

Coefficient of Friction Values

Pattern	Before Grooving	After Grooving
1/8" x 1/8" @ 1/2"	0.37	0.38
1/8" x 1/8" @ 1"	0.36	0.36
1/8" x 1/8" @ 3/4"	0.38	0.39
.095 x 1/8" @ 3/4"	0.38	0.39
Style A	0.40	0.44
Style 15	0.39	0.45

Note: These coefficient of friction readings were obtained under the test conditions of locked wheel, smooth tire, wet pavement and a speed of 50 mph. (Test Method No. California 342-C)

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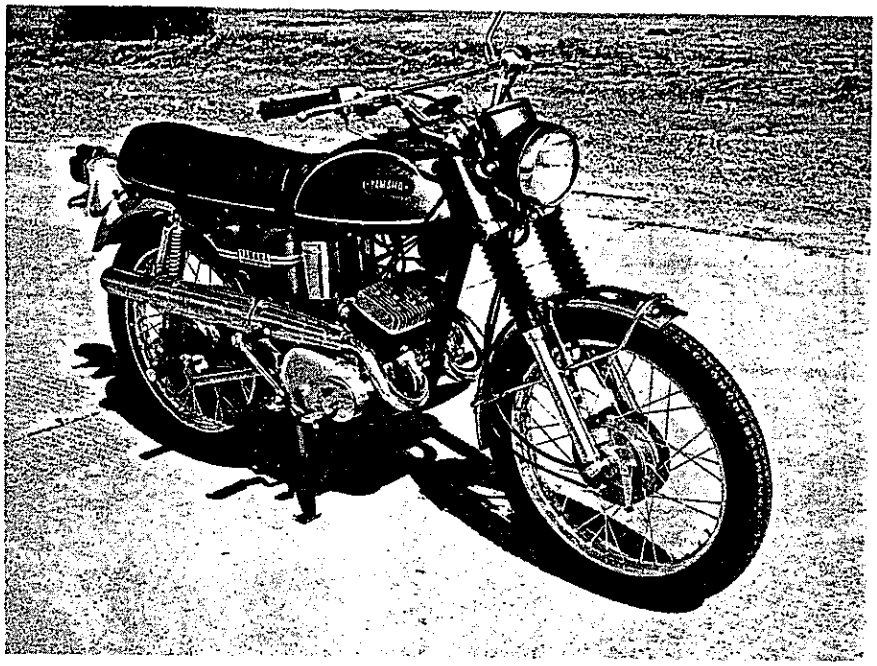
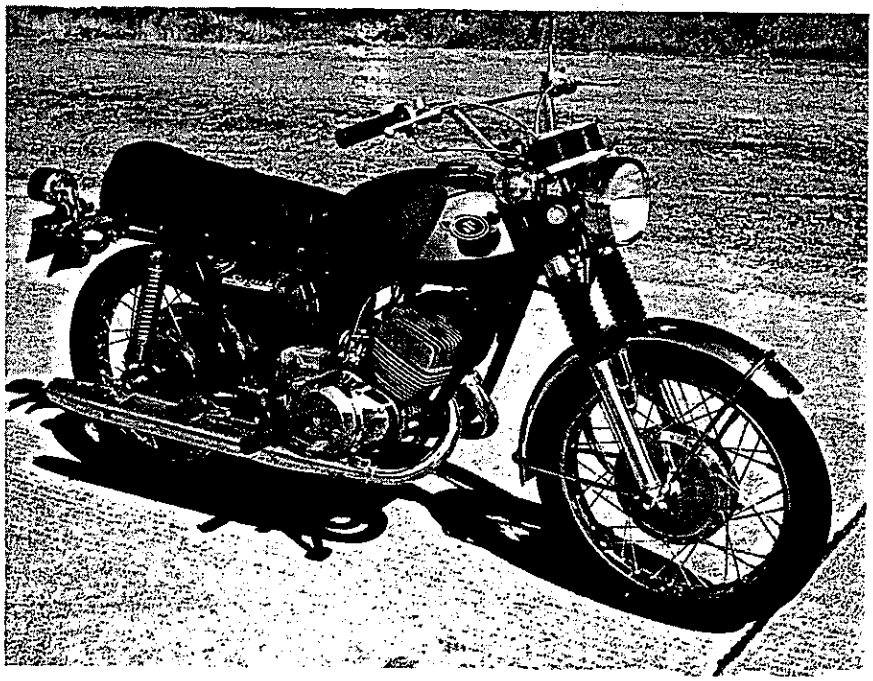
Figure 2
Motorcycles Used in Study



125cc Machine



250cc Machine

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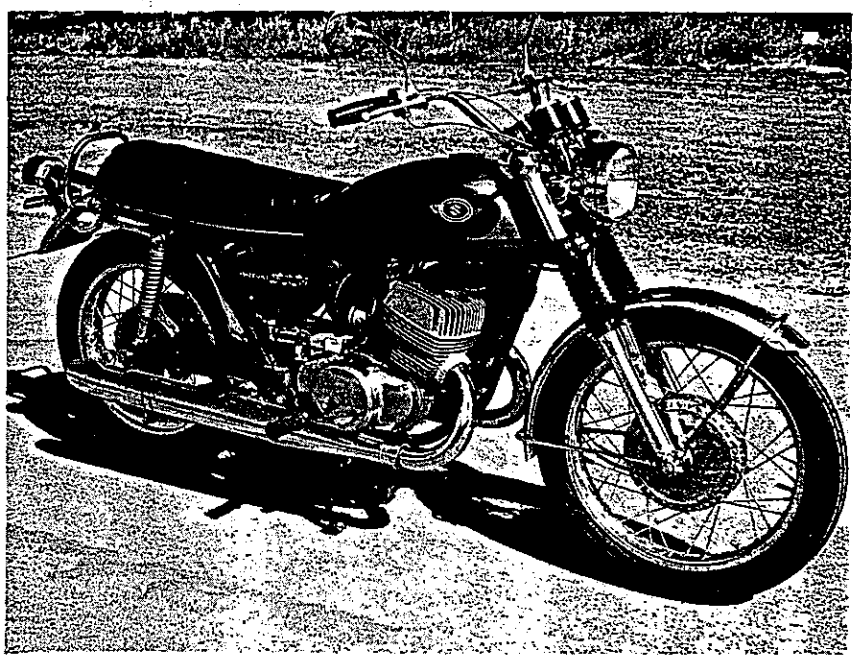
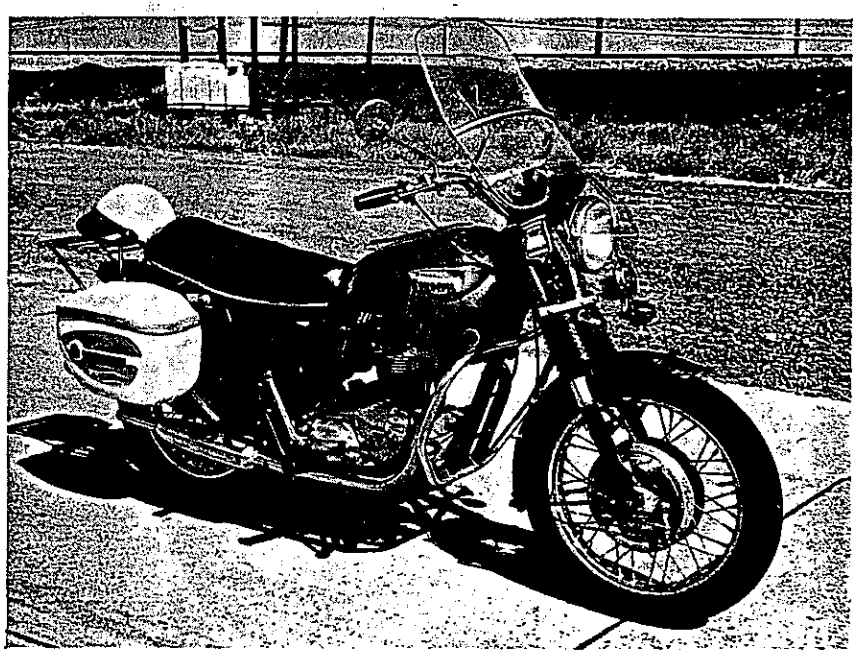
Figure 2 - Cont'd
Motorcycles Used in Study



500cc Machine



650cc Machine

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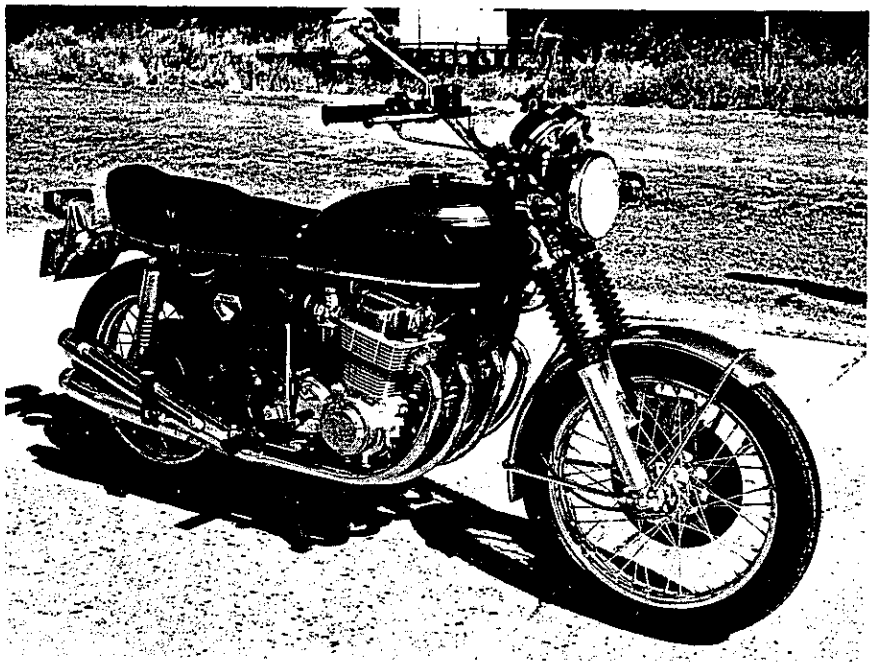
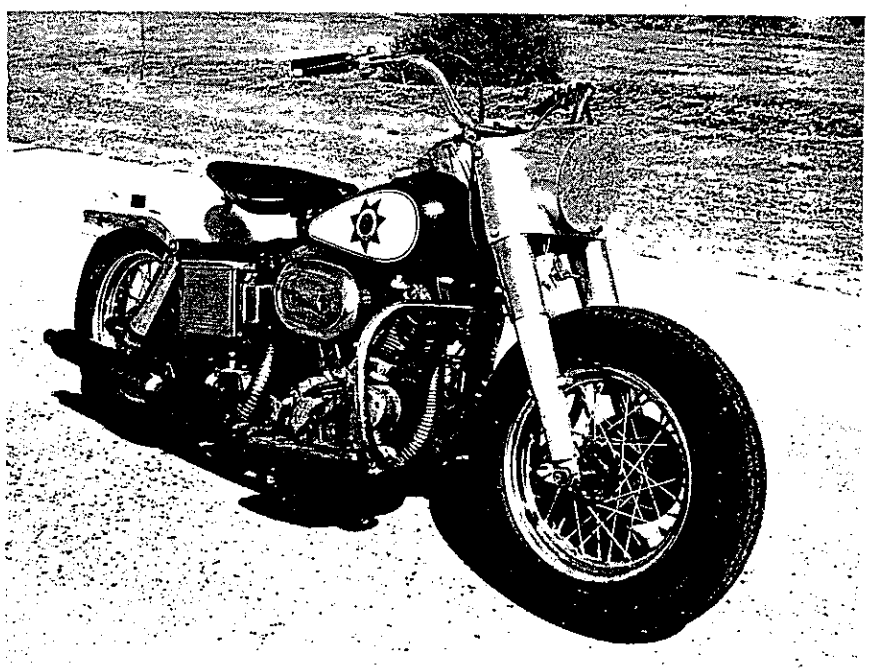
Figure 2 - Cont'd
Motorcycles Used in Study



750cc Machine



Heavy U.S. Machine

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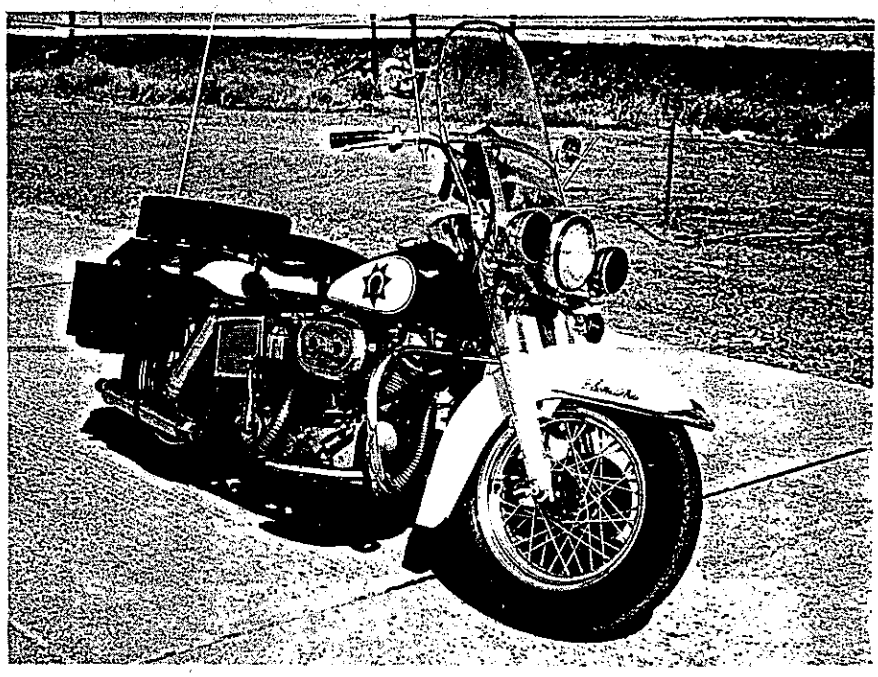
Figure 2 - Cont'd
Motorcycles Used in Study



CHP Machine

Figure 3
Semi-Knobby Tire Used on 125cc Machine

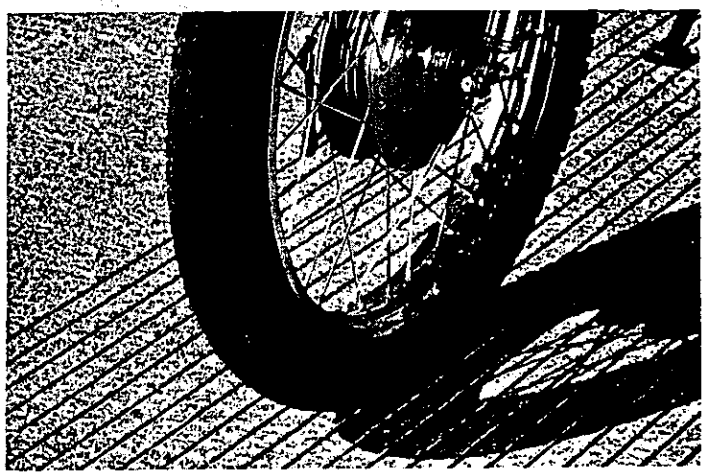


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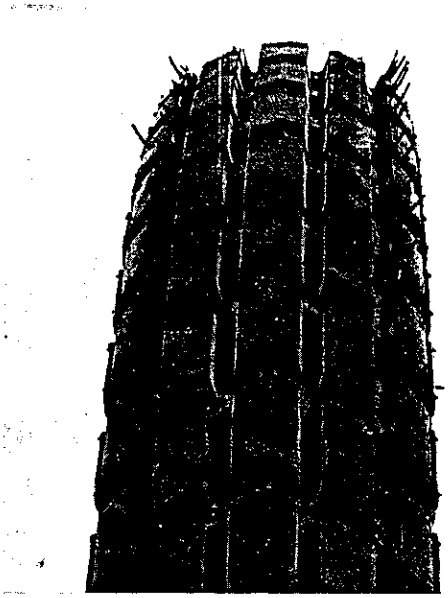
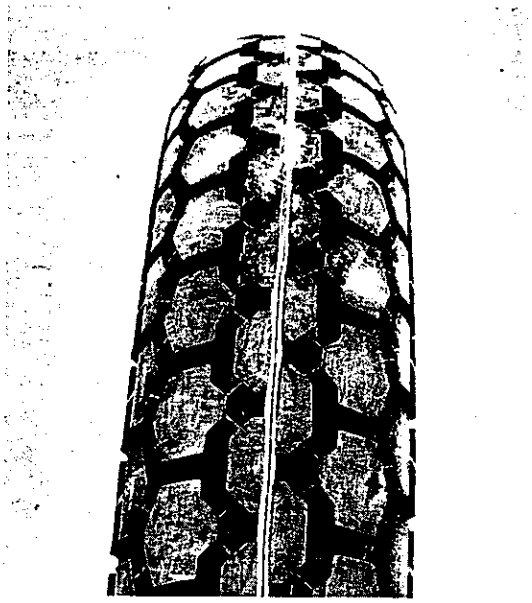
Figure 4
Knobby Tires Used in Study

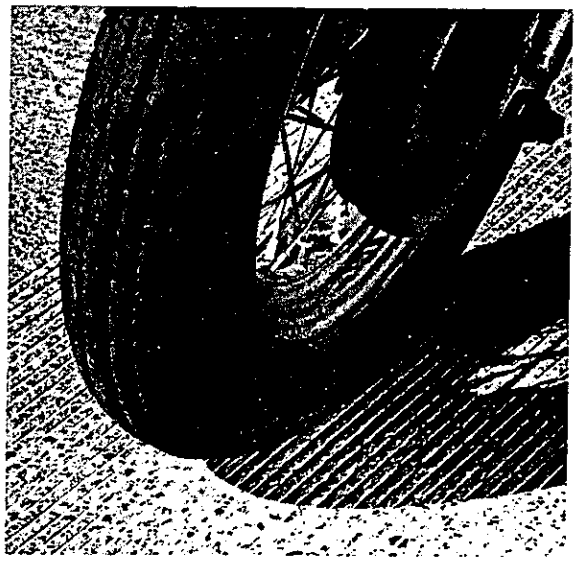


Used on 500cc Machine

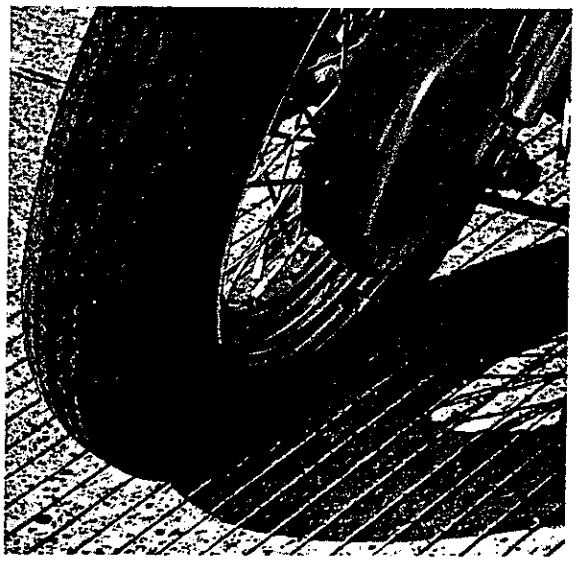


Used on 250cc Machine

Figure 5
Old and New Style CHP Tires



Old Style
(5.00 x 16)



New Style
(5.10 x 16)

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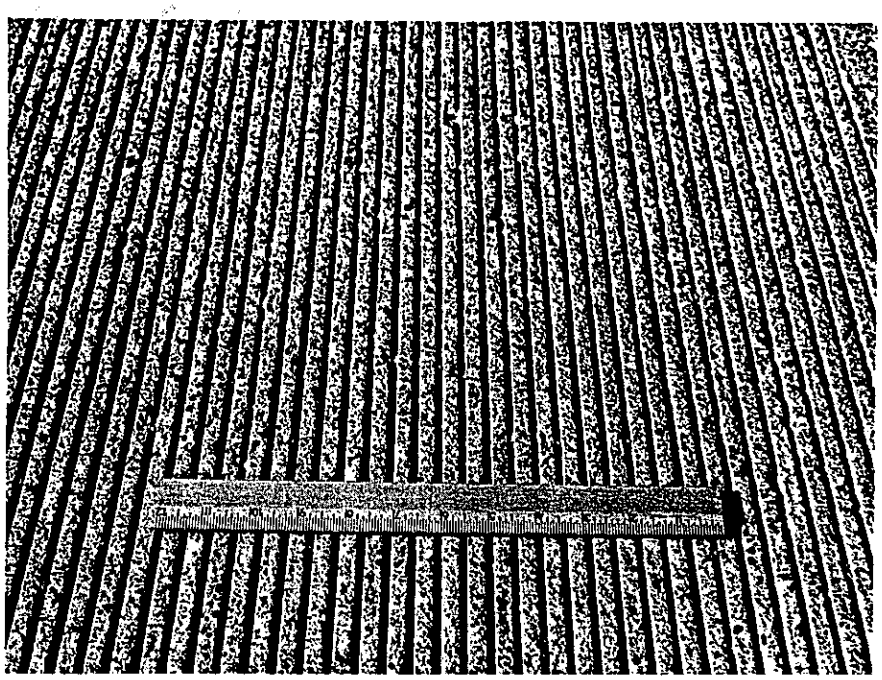
Figure 6

1/8" X 1/8" AT 1/2" CENTERS GROOVING PATTERN MOTORCYCLE VS RELATIVE SENSITIVITY



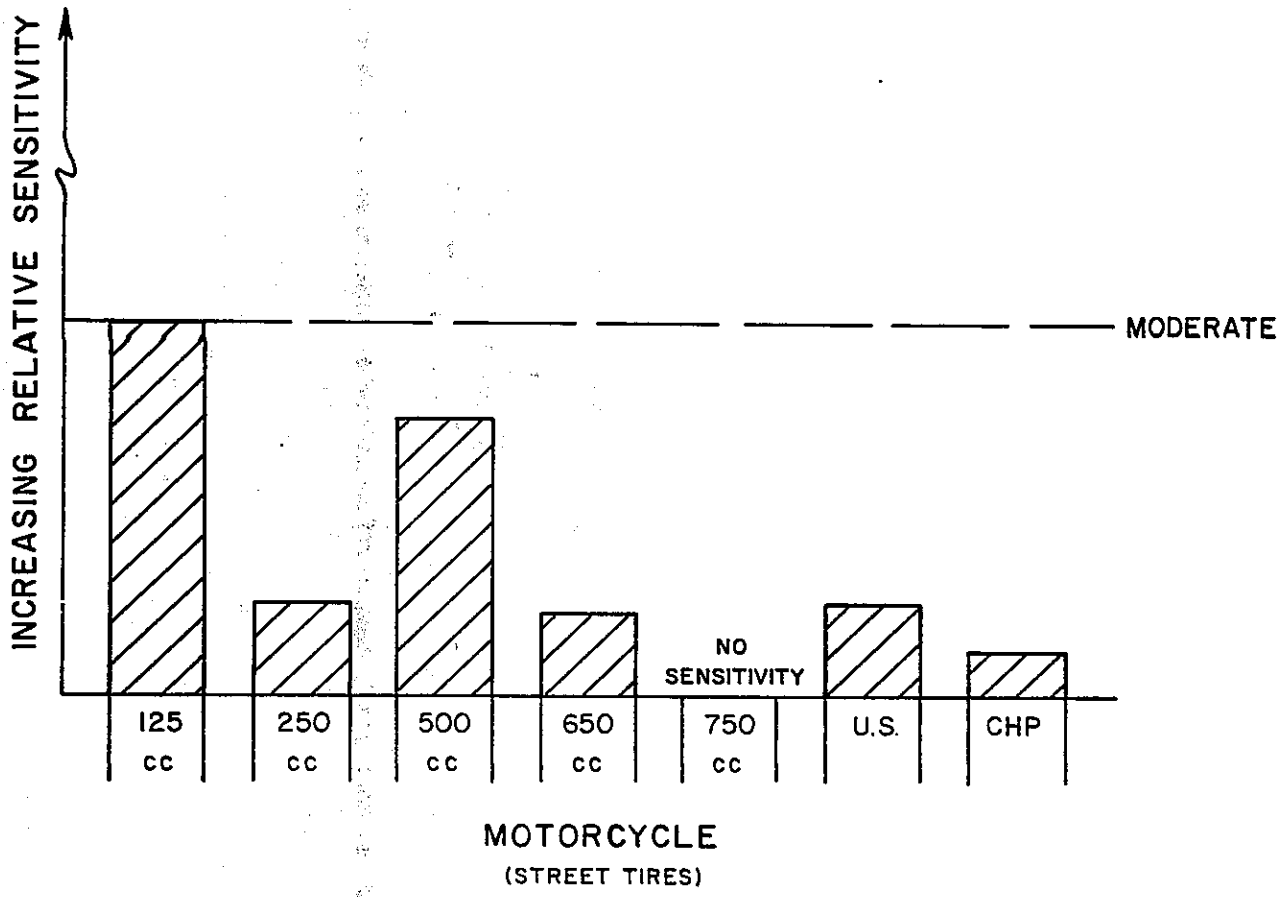


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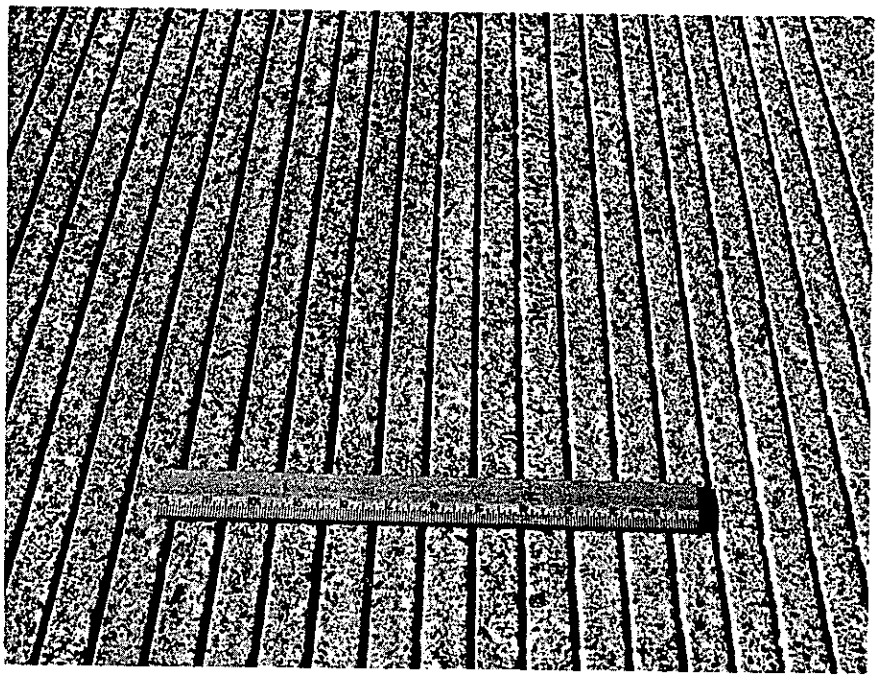
Figure 7

1/8" X 1/8" AT 1" CENTERS GROOVING PATTERN MOTORCYCLE VS RELATIVE SENSITIVITY



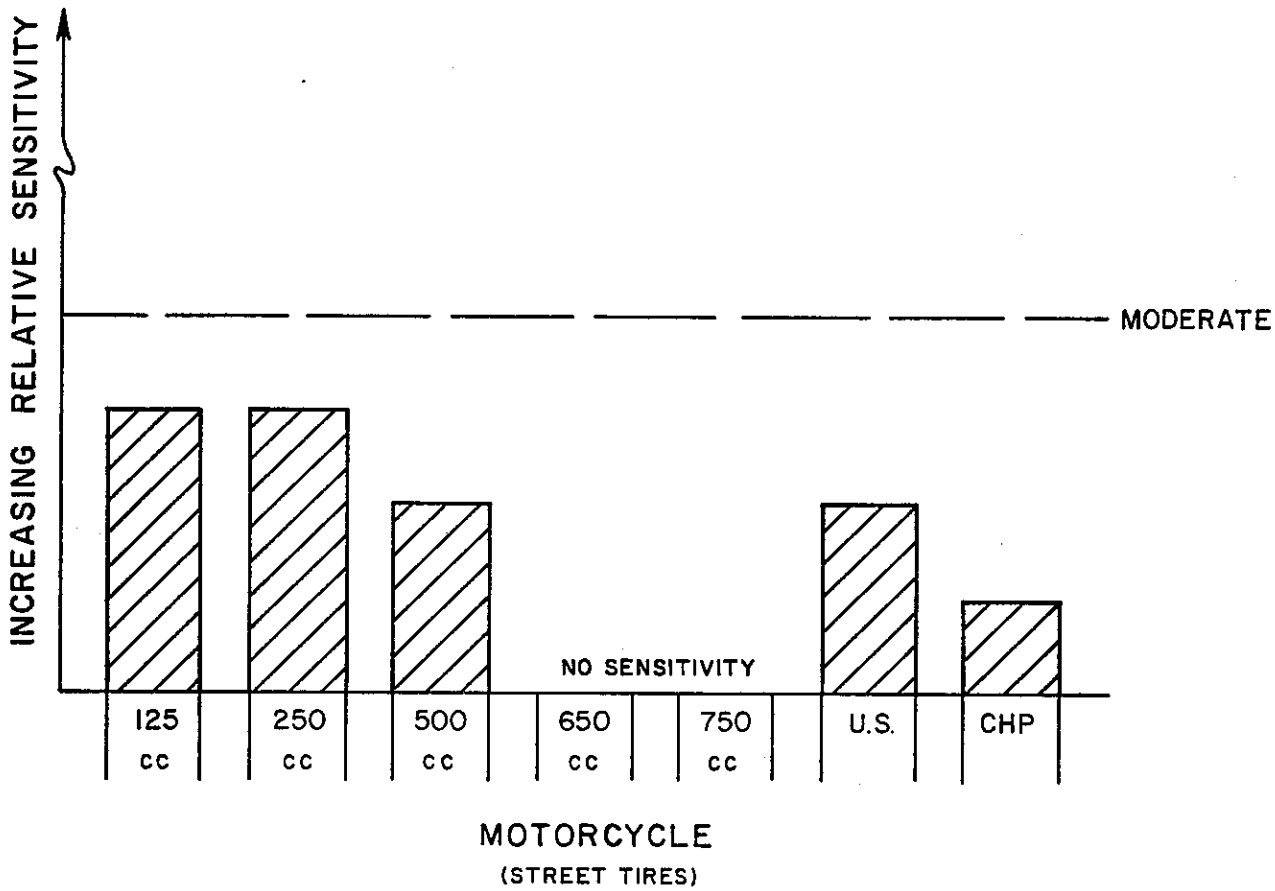


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Figure 8

1/8" X 1/8" AT 3/4" CENTERS GROOVING PATTERN MOTORCYCLE VS RELATIVE SENSITIVITY

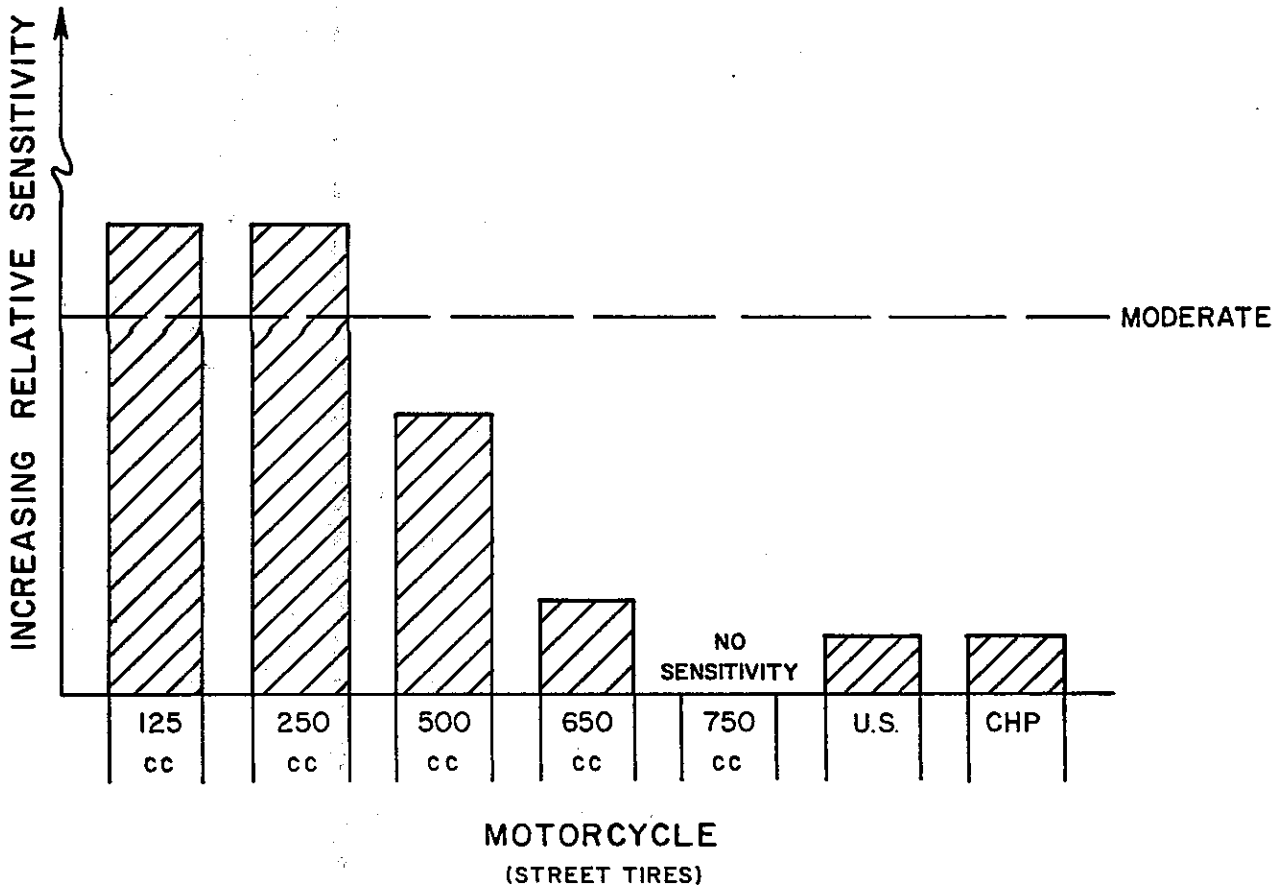

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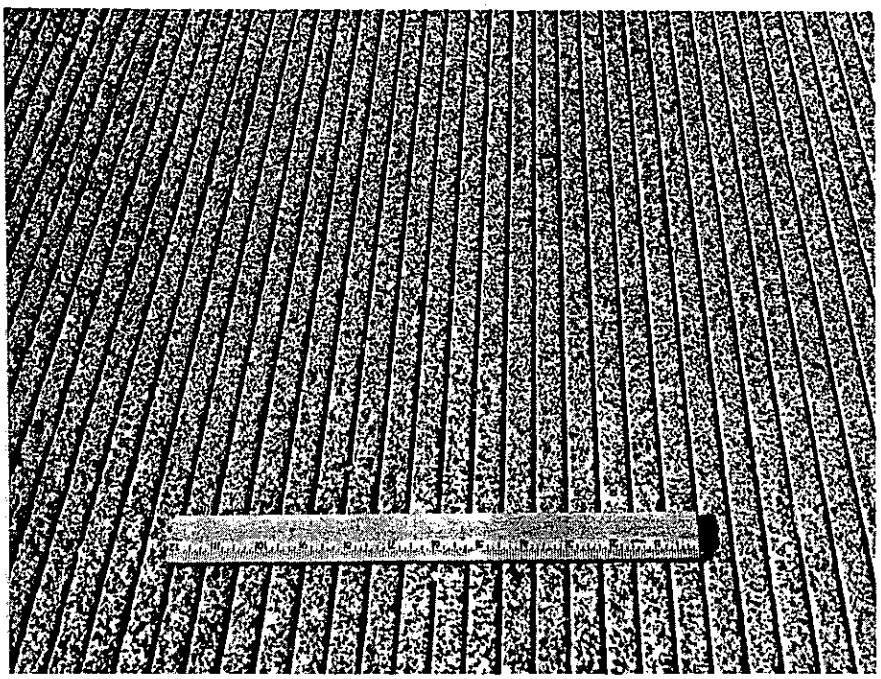
Figure 9

095" X 1/8" AT 3/4" CENTERS GROOVING PATTERN MOTORCYCLE VS RELATIVE SENSITIVITY



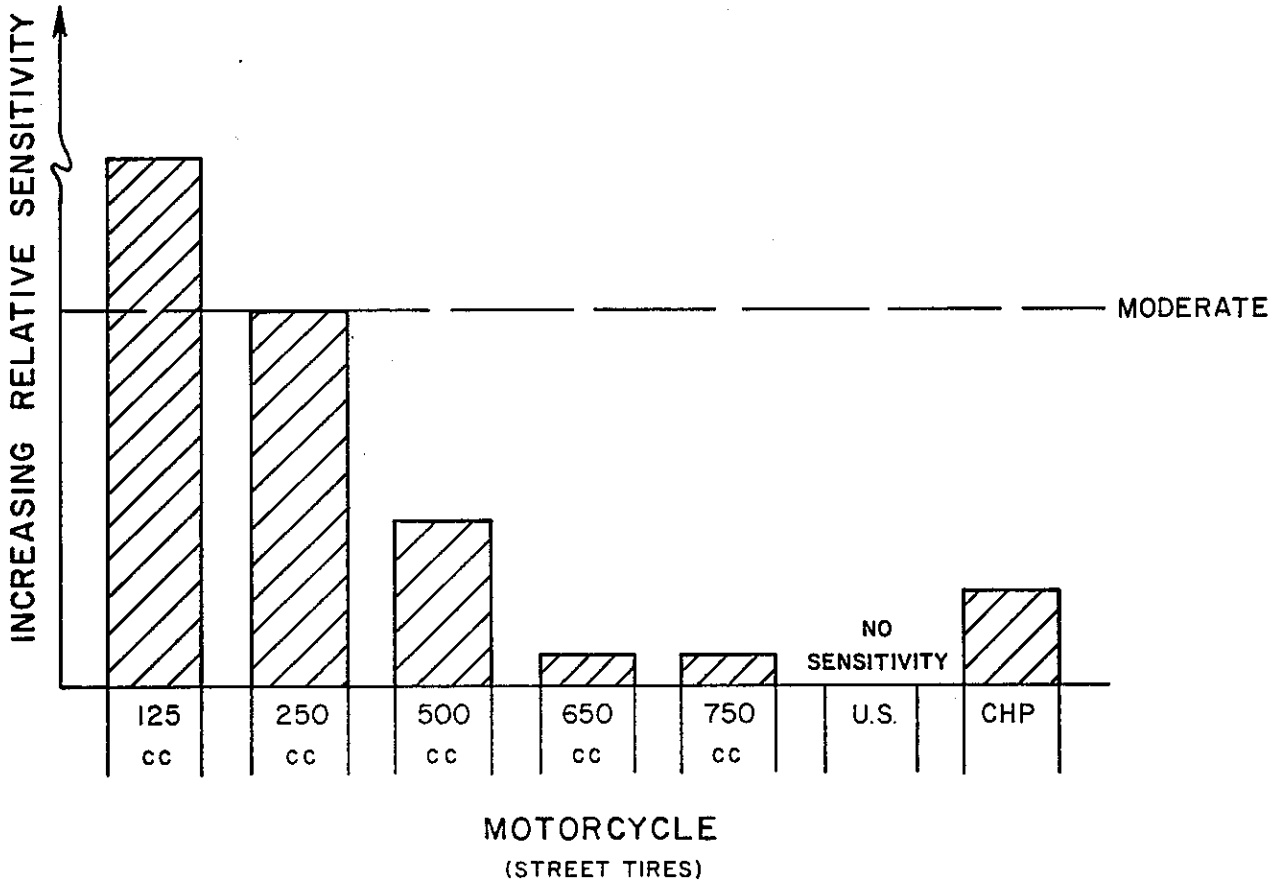


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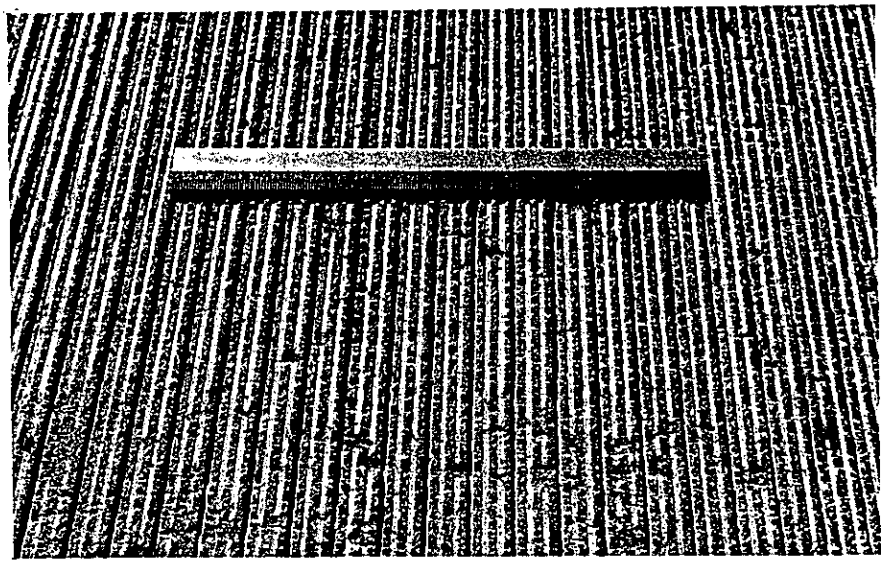
Figure 10

STYLE A GROOVING PATTERN MOTORCYCLE VS RELATIVE SENSITIVITY



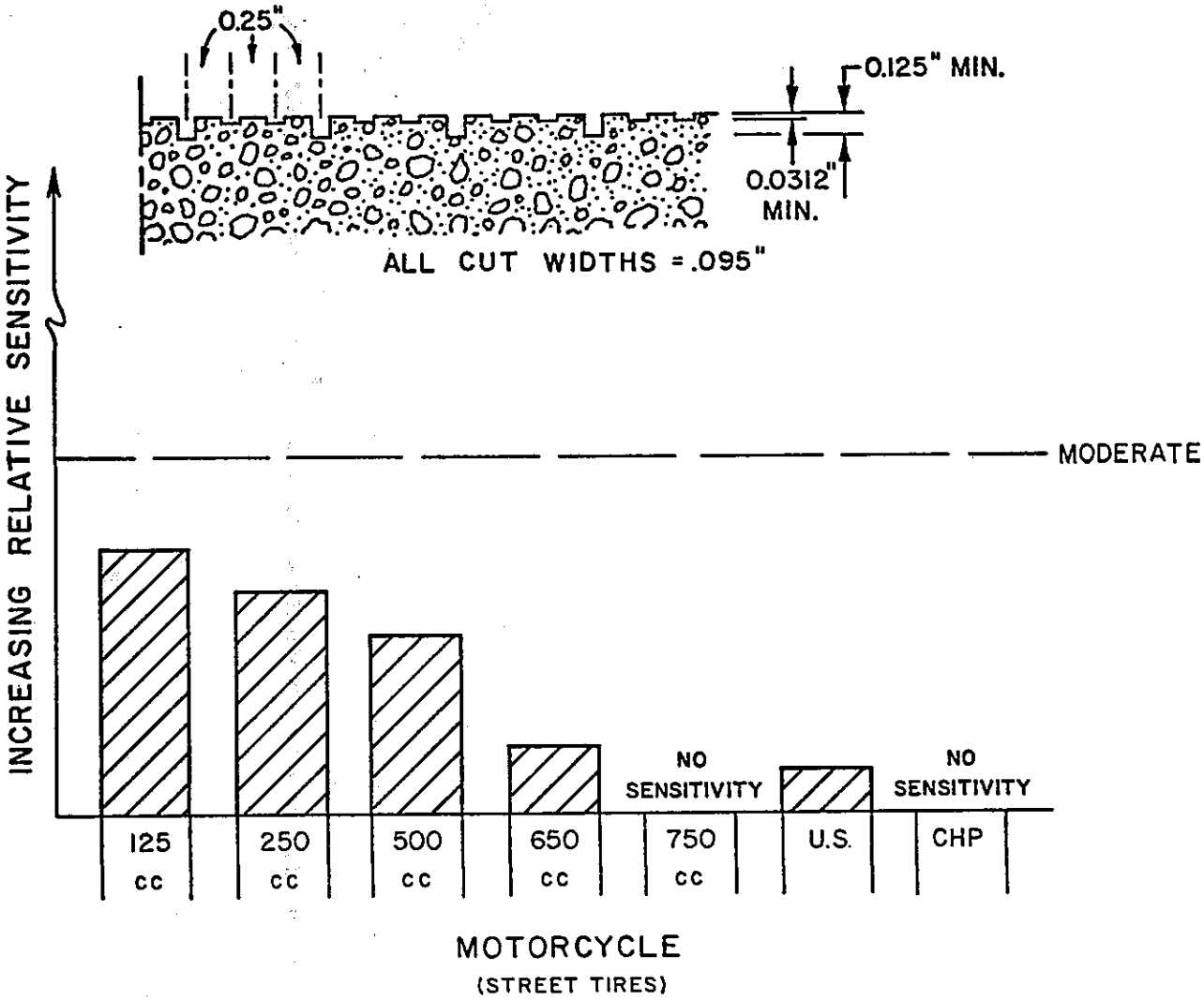


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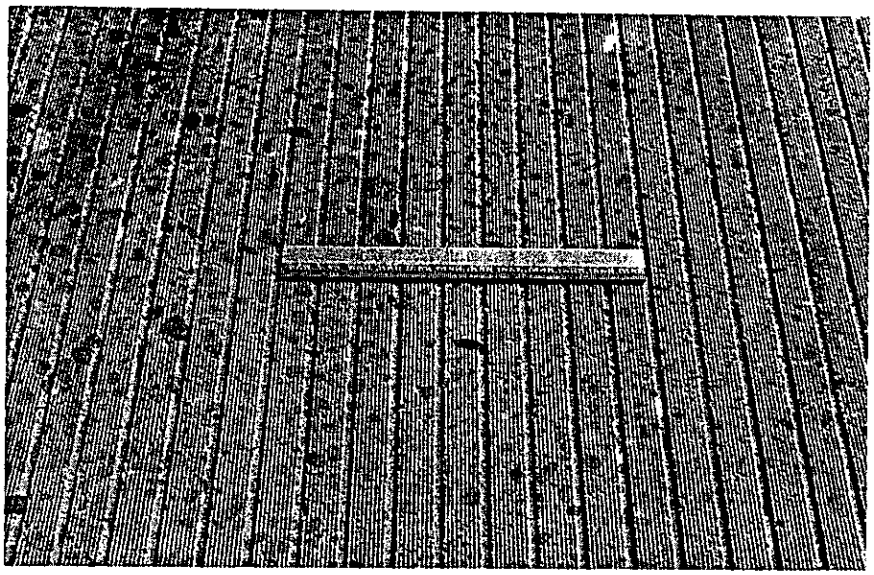
Figure 11

STYLE 15 GROOVING PATTERN MOTORCYCLE VS RELATIVE SENSITIVITY



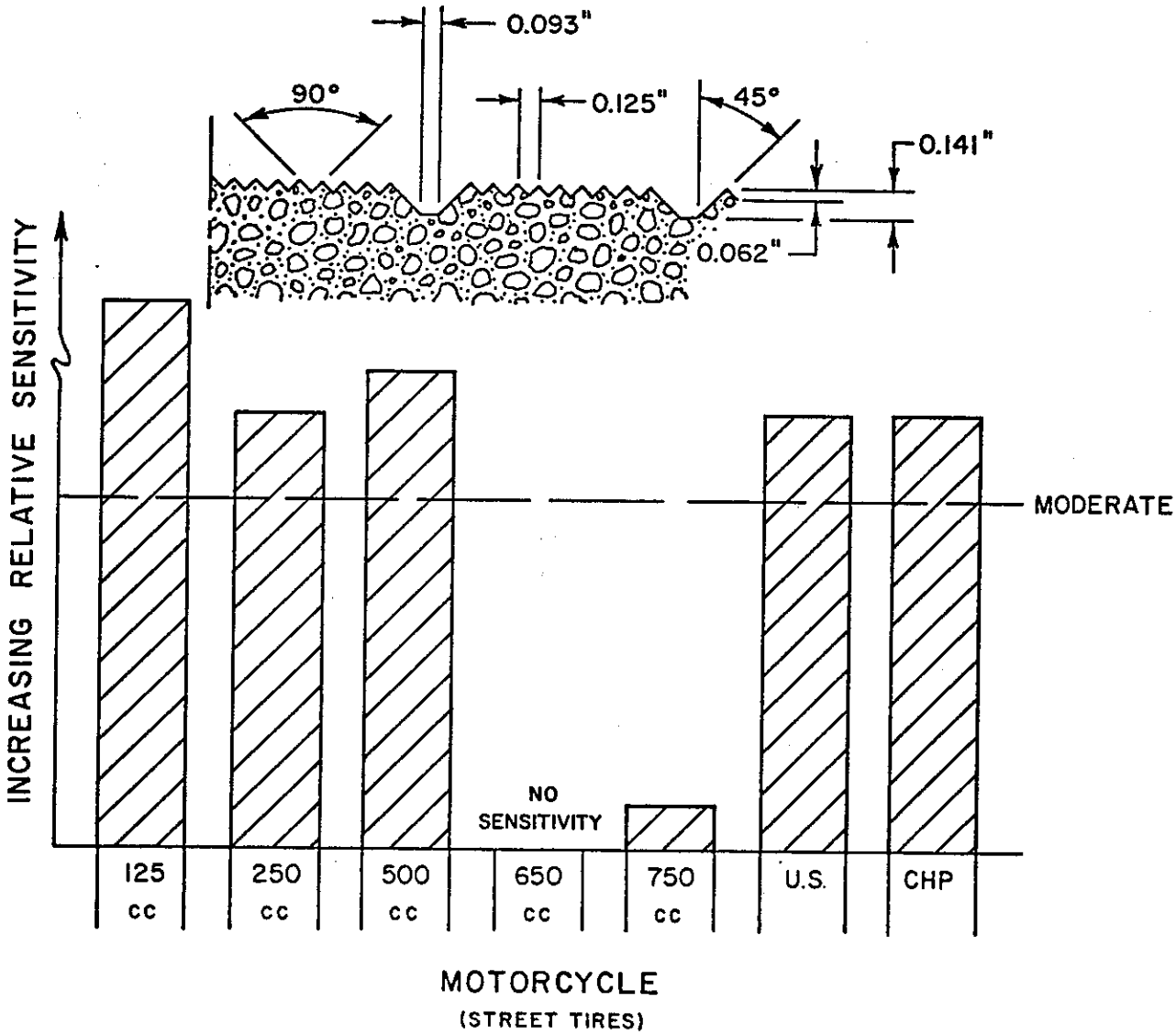


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Figure 12

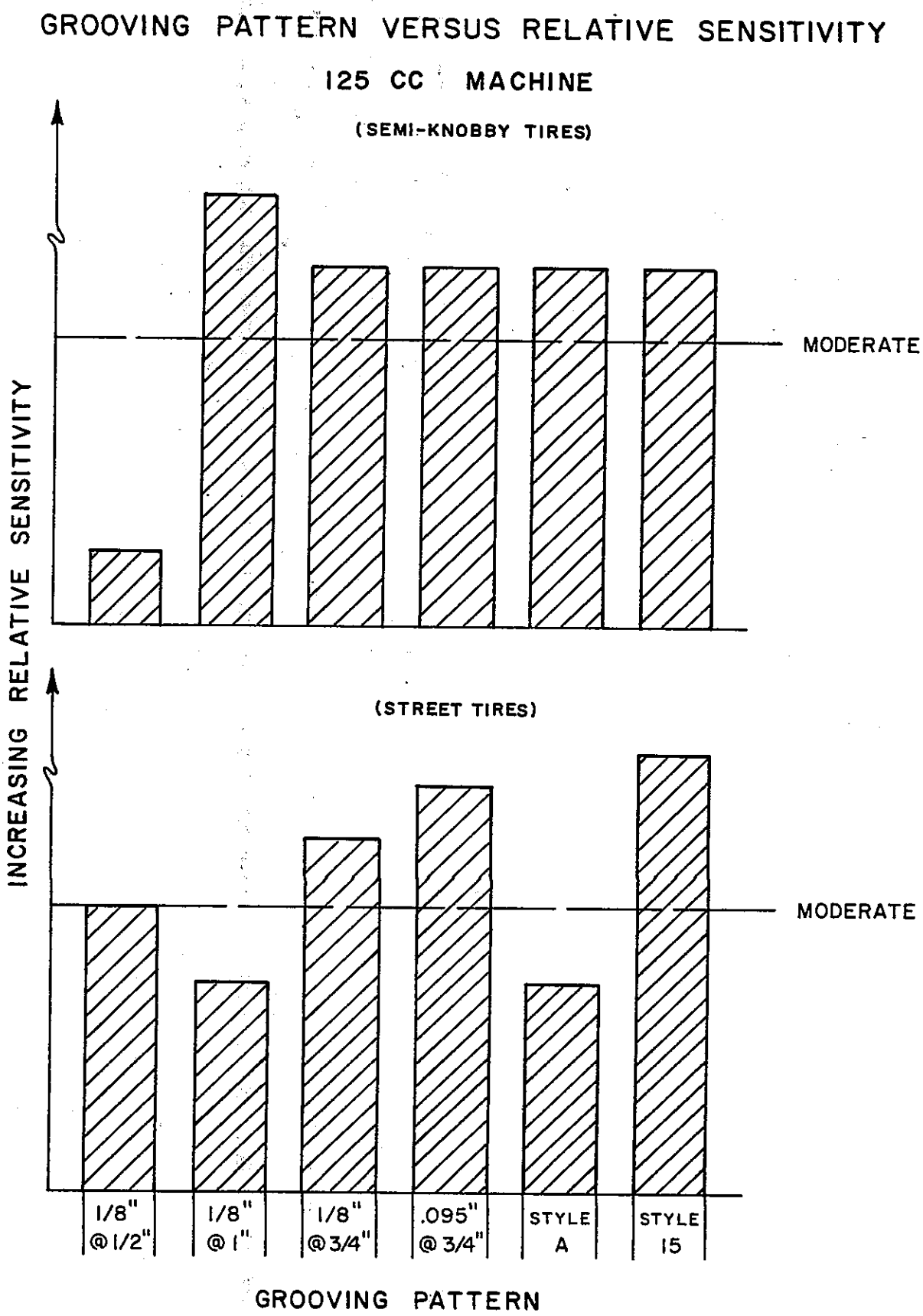

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Figure 13

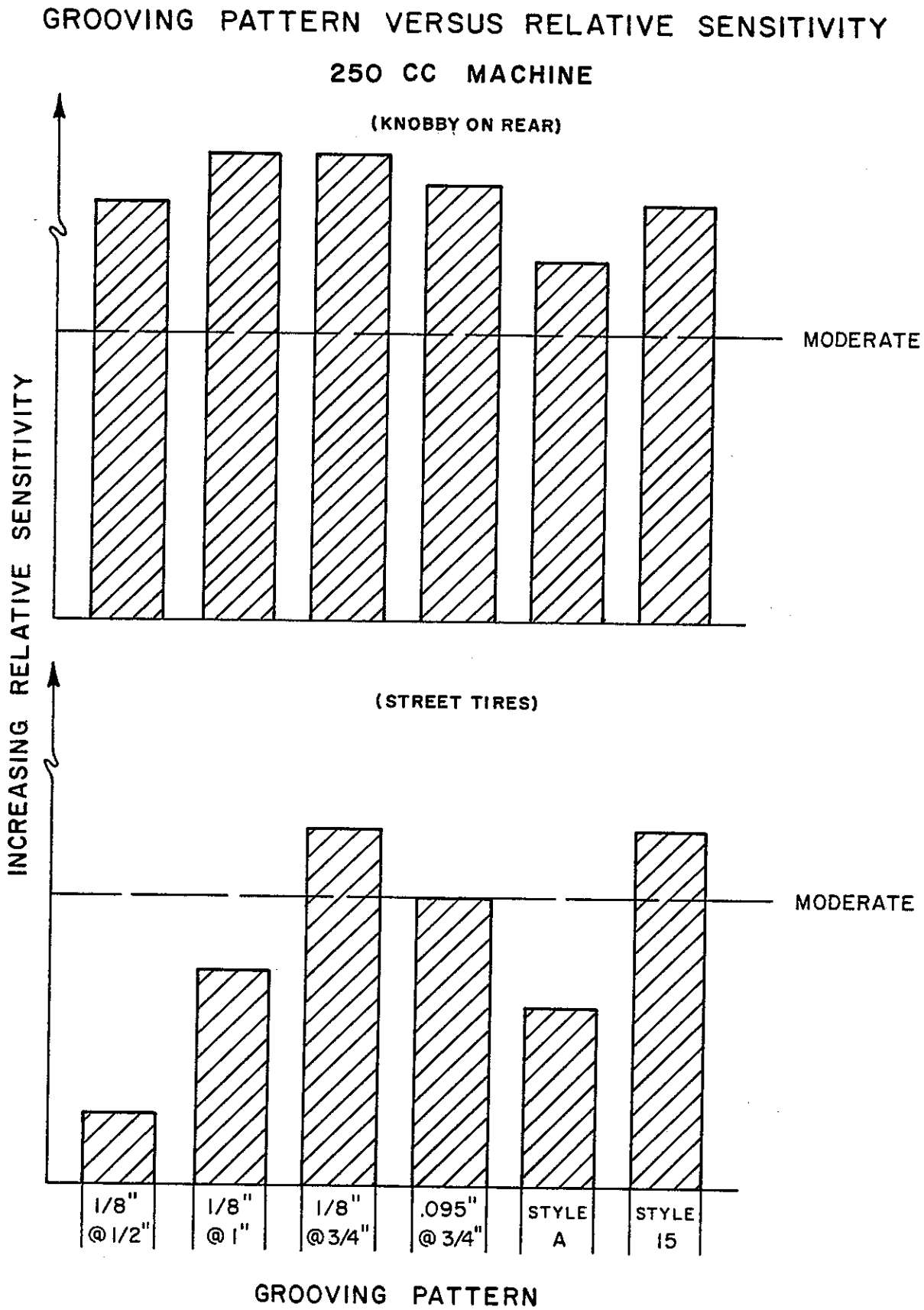

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Figure 14

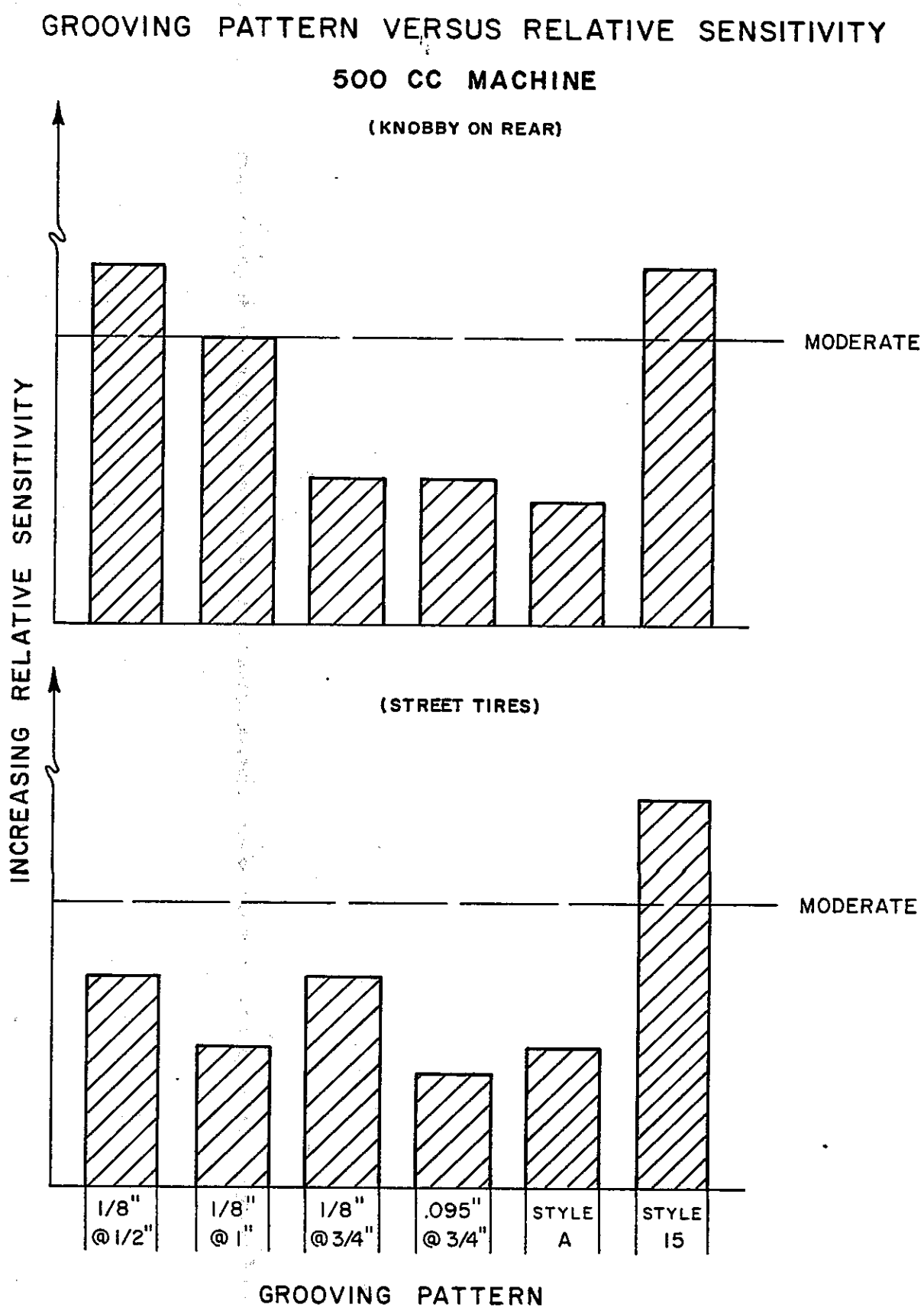

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Figure 15

GROOVING PATTERN VERSUS RELATIVE SENSITIVITY

650 CC MACHINE

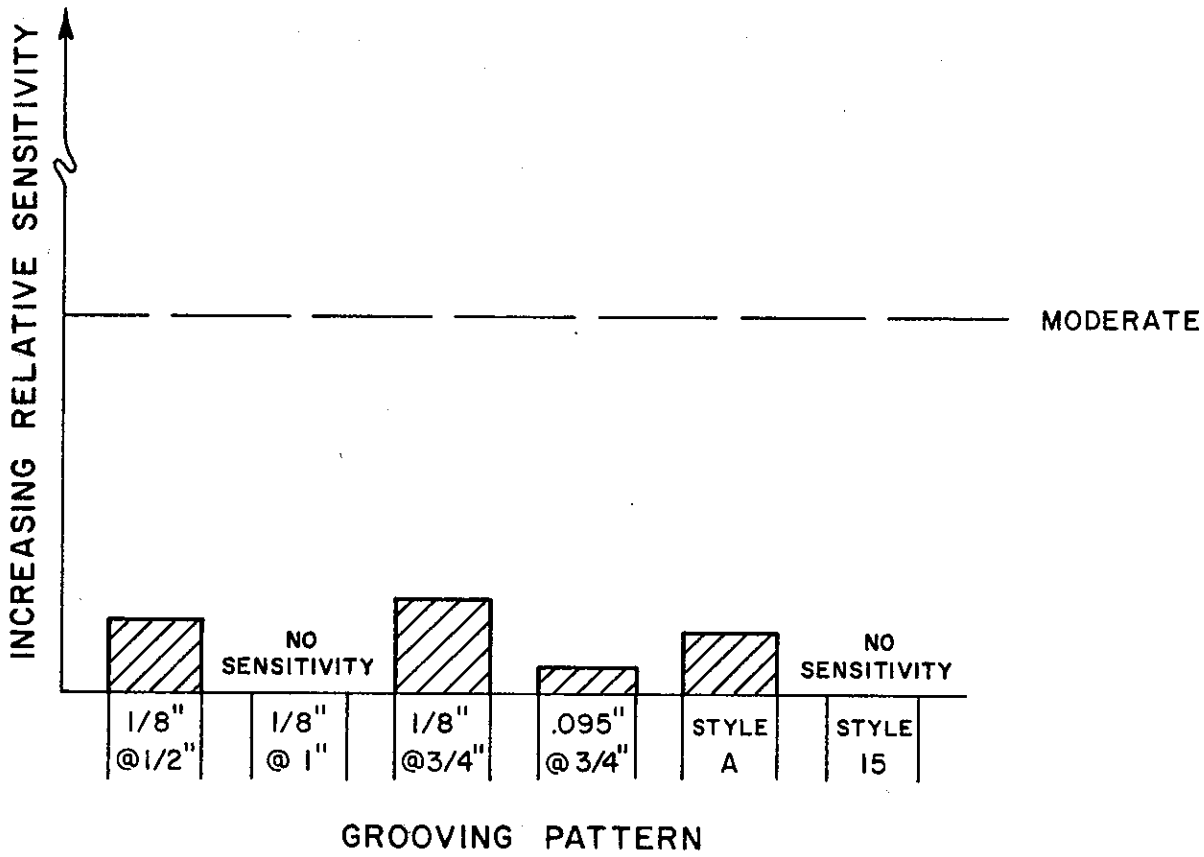

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Figure 16

GROOVING PATTERN VERSUS RELATIVE SENSITIVITY

750 CC MACHINE

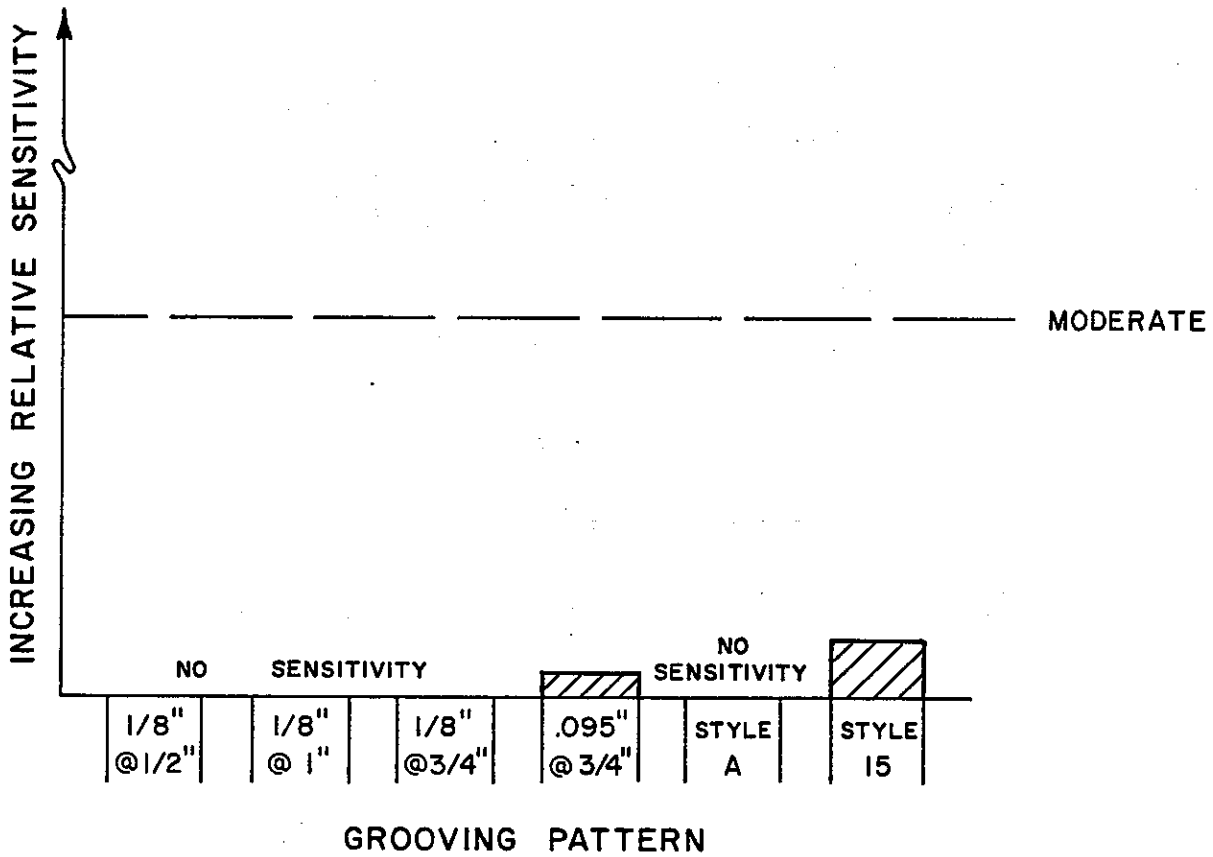

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Figure 17

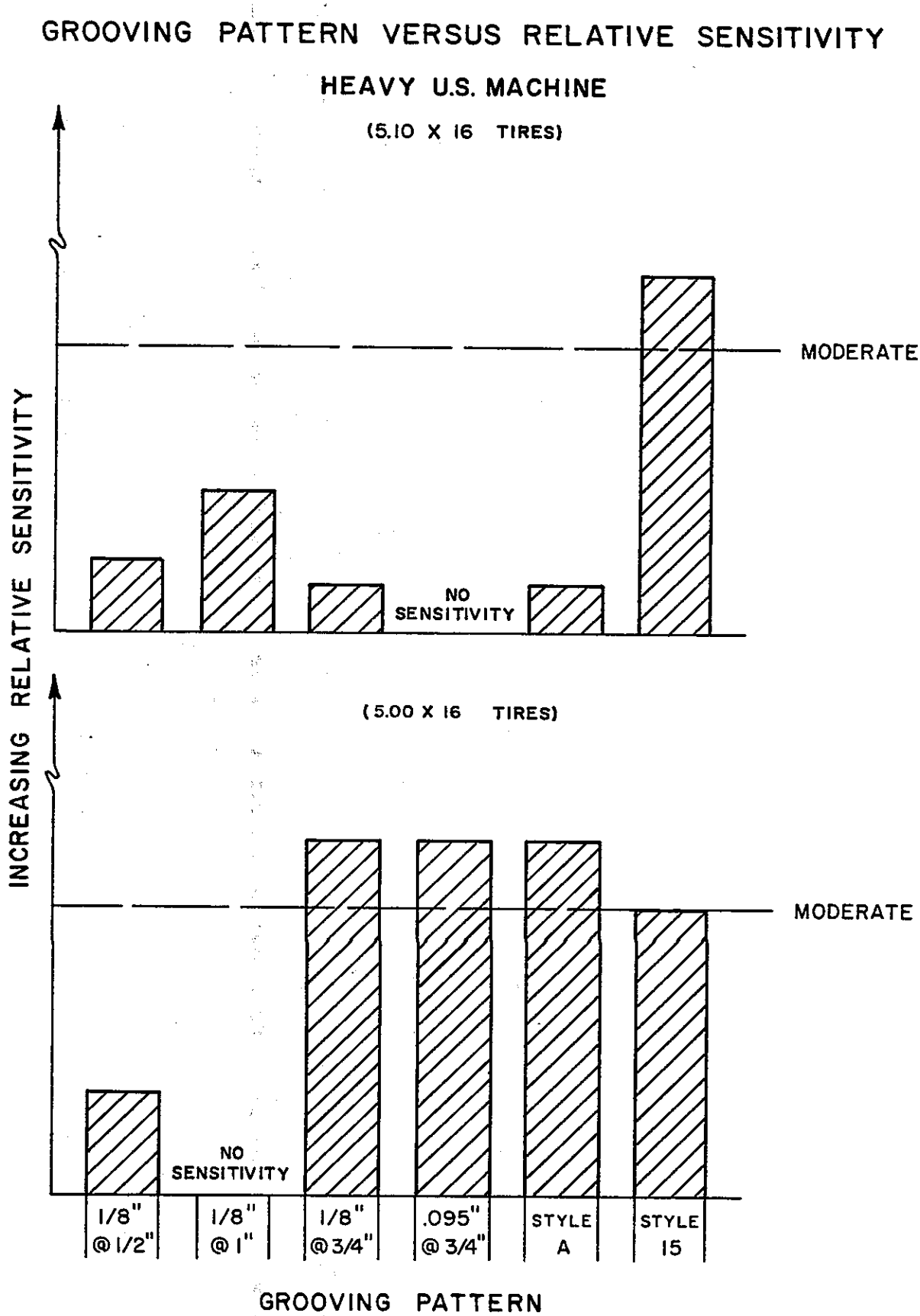

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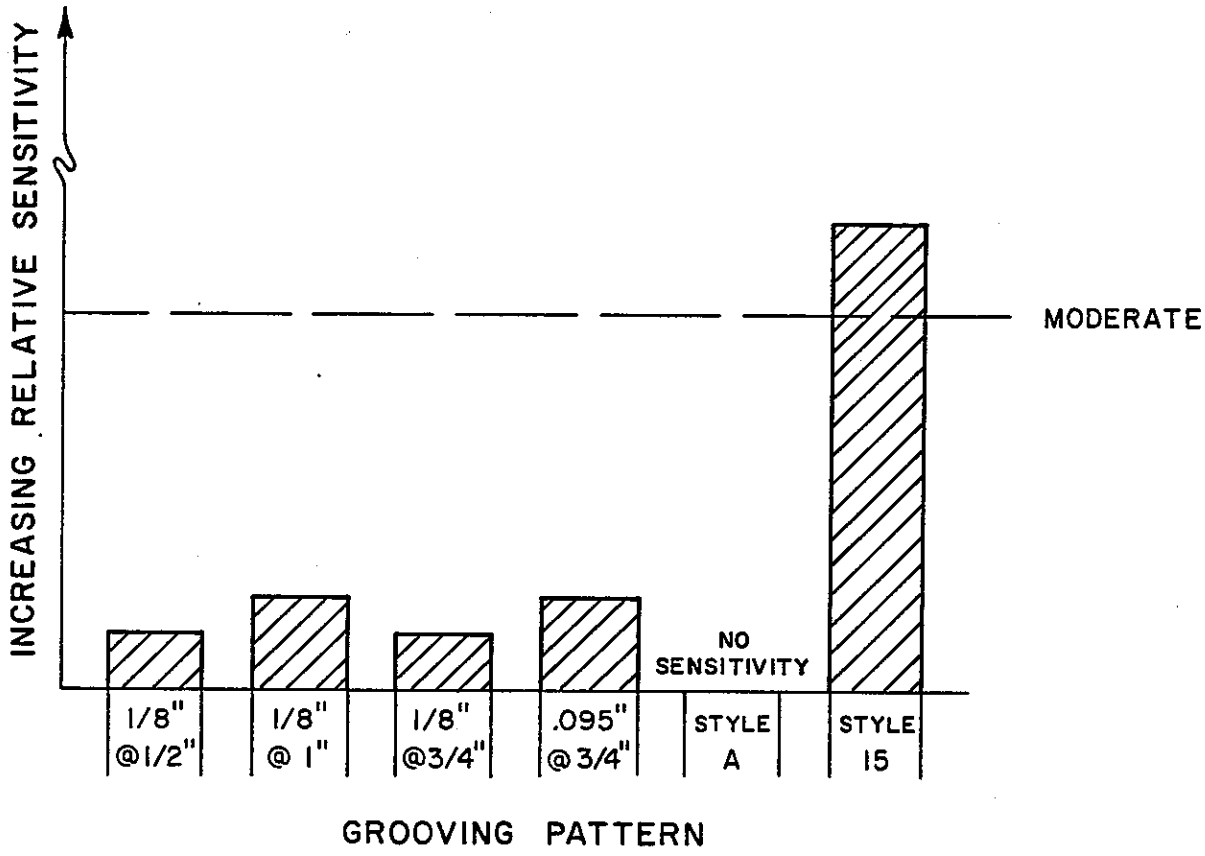
Figure 18

GROOVING PATTERN VERSUS RELATIVE SENSITIVITY

CHP MACHINE

(5.10 X 16 TIRES)



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(Delete Para. 6 if not applicable.)

(The grooved width shown on the plans should be 2 feet less than the lane width rounded to the nearest foot, except that it should never be less than 9 feet.)

GROOVE EXISTING CONCRETE PAVEMENT.--The surface of existing concrete pavement shall be grooved at the locations and to the dimensions shown on the plans. Said grooving shall conform to the requirements of these special provisions.

Grooved areas shall begin and end at lines normal to the pavement center line and shall be centered within the lane width. 2

Grooving blades shall be 0.095-inch wide ± 0.003-inch and shall be spaced 3/4 inch on centers. The grooves shall be cut not less than 1/8 inch nor more than 1/4 inch deep. The grooves on bridge decks shall be cut not less than 1/8 inch nor more than 3/16 inch deep. 3

The actual grooved area of any selected 2-foot by 100-foot longitudinal area of pavement specified to be grooved shall be not less than 95 percent of the selected area. Any area within the selected area not grooved shall be due only to irregularities in the pavement surface and for no other reason. 4

Residue from grooving operations shall not be permitted to flow across shoulders or lanes occupied by public traffic or to flow into gutters or other drainage facilities. Solid residue resulting from grooving operations shall be removed from pavement surfaces before such residue is blown by the action of traffic or wind. 5

The noise level created by the combined grooving operation shall not exceed 86 dbA at a distance of 50 feet at right angles to the direction of travel. 6

Pavement grooving will be measured by the square yard. The quantity of pavement grooving to be paid for will be determined by multiplying the width of the grooved area by the total horizontal length of lane grooved. 7

The contract price paid per square yard for groove existing concrete pavement shall include full compensation for furnishing all labor, materials, tools, equipment and incidentals and for doing all work involved in grooving the existing concrete pavement, including removing residue, as shown on the plans, as specified in these special provisions, and as directed by the Engineer. 8

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