UNITED STATES DEPARTMENT OF AGRICULTURE

FOREST SERVICE

MOTOR GRADER TEST

Report of

Austin-Western - Model 99-H

San Bernardino National Forest

January 23 - March 15, 1950

by

Division of Engineering

and

Arcadia Equipment Development Center

Region 5 - Forest Service

U. S. Department of Agriculture

MOTOR GRADER TEST

Report of

Austin-Western - Model 99-H

San Bernardino National Forest

January 23 - March 15, 1950

by

Division of Engineering

and

Arcadia Equipment Development Center

Region 5 - Forest Service

U. S. Department of Agriculture

TABLE OF CONTENTS

Subject Heading (cont.) | Page

Subject Heading (cont.)		Page

Field Tests (cont.)

Tables & Figures

Tables and Figures (cont.)

Tables and Figures (cont.) Page

INTRODUCTION

The grader test described in this report is the result of an effort on the part of the Division of Engineering to determine the adequacy of commercial units offered on bid invitation to perform in accordance with the rigid requirements of the field. This report is on one unit of the Motor Grader Test Project conducted on the San Bernardino National Forest, January 23 to March 15, 1950.

Originally scheduled for two units, the project was expanded at the request of manufacturers to include five companies and five graders ranging from the 22,000 lb. to the 27,000 lb. classes.

This is one of the individual reports prepared for each of the five graders tested. The results of the entire test project are summarized in a composite In-Service, Confidential report which includes a more general analysis and encompasses a wider scope in objectives.

The actual field testing of the graders was divided into two major sections (1) physical characteristics, and (2) field performance.

The first section, referred to as the "flat land" test, consists essentially of observations as to physical design characteristics. This includes such items as clearances, blade maneuverability, turning radius, observations on operational features, visibility, operation of controls, and other such data as would be apparent from a detailed inspection of the machine.

The second section consists of a series of field tests designed to simulate the various field operations normally encountered in routine truck trail maintenance on the National Forests. Such operations as bank sloping, drainage dip construction, three-pass road maintenance, finish grading and several others are included to establish the field operation characteristics of the grader tested.

Every effort has been made to assure comparable test conditions for all graders. Standard procedures were devised, quantities and distances measured, and particular attention paid to soil conditions. Operators were given an instruction period prior to test and allowed to use the machine until such time as they were considered competent by company representatives or, in their absence, road foremen skilled in the use of patrol graders. Company representatives were encouraged to request re-runs where they felt conditions adverse or their machine capable of better performance.

AUSTIN WESTERN 99-H GRADER

The grader furnished for the test was a Model 99-H manufactured by the Austin Western Company of Aurora, Illinois. The unit was rated heavy class, with all-wheel drive and steer, and had hydraulic control throughout. It was equipped with low pressure tires, cab, scarifier and 13-foot blade. The grader was powered by a 76 horsepower I.H.C. UD-14A diesel engine.

Fig. 1. Austin Western 99-H Grader

DESCRIPTION OF TESTS

Section 1

Flat Land Tests

The first phase of the "flat land" test was the obtaining of data covering weights, dimensions, clearances, engine data, fuel requirements, and the other facts concerning the machine as usually given on manufacturers' specification sheets. Data taken from specification sheets and from the inspections are tabulated for comparison and shown as columns 1 and 2 of Table 1, Test Results Section of the report. In most cases the data agreed with that of the manufacturer but in a few instances notable variations were obtained.

The second phase of the "flat Land" tests consisted of an appraisal of the other physical characteristics of the machine as applied to its various functions. The following tests were performed:

I. <u>BLADE OPERATION</u>

The purpose of this test was to determine the maneuverability of the blade and time required for movement from one position to another.

Equipment used consisted of protractor, tape, plumb bob, stop watch, straight edge, still and movie cameras.

The machine was set on a flat concrete slab. Three reference lines were established; one at the machine fore and aft center line; and one on each side of center, running from the inside of the front tires to the inside of the rear tires. All measurements taken were from these reference lines. Center position of the blade was established as that condition at which, with the blade touching the slab, the blade and circle were centered with the machine. Normal position of the blade was established as that position of the blade in which the machine could operate most advantageously with no change in lift arms or linkage. One cycle of blade circle operation was defined as 360° in the case of machines with full revolving blade, or in case of machines not full revolving the maximum degrees of turn of the blade between obstructions.

A. <u>Operation of Circle.</u> Measurements of time and angle of cycle were taken. Observations were made regarding possibility of damage to parts of the machine by operation of the blade.

B. <u>Locking Devices.</u> Observations regarding the presence or absence of circle locking devices, location, and whether or not they could be considered positive were recorded.

C. Bank Sloping Positions. Starting from centered and normal operating position, the blade was moved to maximum bank sloping angle without moldboard shift. Height of blade tip above ground, bank slope angle, position of heel of blade on ground with respect to the tire reference line, and time to shift to this position were recorded.

The moldboard was then shifted for maximum reach and the blade was set at $1\frac{1}{2}$:1, 1:1, 3/4:1, $\frac{1}{2}$:1 and 1/4:1 bank sloping positions. Height of tip of the blade above ground and position of heel of the blade with respect to the tire reference line were recorded. The time required to shift from blade centered, normal operating position to the maximum bank sloping angle was recorded. Still pictures of each bank slope position were taken.

D. Side Shift. The distance the blade could be moved to right and left of centered position, with and without manual moldboard shifting, was measured. The time required for each operation was also recorded. In all cases distances were measured with the cutting edge of the blade resting on the concrete slab. The crew to shift the moldboard manually was limited to the operator and one helper.

E. Blade Lift. With linkage set for normal operation position, measurements were made and time recorded for movement of the blade from ground level to maximum lift position, and also maximum depth below ground, using a pit for this purpose. The number of holes on lift links and the distance of possible adjustment was recorded.

Starting with blade and circle in center position and at right angles to center line of machine the maximum blade lift angle, both right and left, was measured. Links were adjusted as necessary but the blade was not rotated on the circle for this operation.

The height of the lowest point of the circle with the blade at ground level was measured.

F. Blade Reverse. Ability to reverse the blade was recorded. This test concicted of setting the blade at 45° for casting material to the right, then turning blade for backing up, so as to continue casting material in the same direction.

G. Pitch Positions. Information obtained on pitch positions was as follows - number of notches, total adjustment distances and the degrees from the vertical both plus (top ahead of bottom), and minus (top behind bottom.)

H. **Visibility.** With the blade centered and at 45°, in both right and left positions, visibility of blade and front wheels was appraised from still photos taken from normal sitting position showing view to right, left, and straight ahead. This procedure was repeated for visibility from a standing position.

Rear view visibility was also noted, with still pictures recording actual views.

II. WHEEL LEAN

The purpose of the test was to determine the degree to which the wheels could be leaned for turning and for resistance to side thrust in operation.

The degrees of lean, both left and right, were recorded, and still shots were taken showing angle as indicated by large protractor.

III. GRADER GROUND CLEARANCE

The purpose was to determine ability of the grader to clear windrows, rock and obstackes which might be encountered either in forward or reverse operation.

With wheels in a vertical position measurements were taken between lowest projections and the ground, behind the blade, and ahead of blade, the latter being limited to 8 inches on either side of center of the front axle. Particular attention was paid to the possibility of damage to steering geometry if it was the lowest projection.

With wheels at maximum lean, measurements were taken in the same manner.

IV. WIDTH OF FRONT TREAD

To determine tread width of graders equipped with oversize tires in front, measurements were taken from center to center of tires, at point of ground contact.

V. SERVICING REQUIREMENTS.

The object of these observations was to determine the time consumed and materials necessary in servicing the equipment.

The number of grease fittings needing daily and weekly service were counted, and time for each service was recorded by equipment service men. Also recorded was the personnel necessary to do a grease job, lubricants and fuel used and types recommended by the manufacturers.

VI. TIRES AND RIMS

To determine adequacy and safety of this equipment, data were recorded regarding ply, size, number, and manufacturer of tires; type of rim and rim association number. At the end of the test, cuts, breaks and wear were recorded, giving reasons when possible. Still pictures were taken to show condition of tires.

VII. TANK CAPACITY

The purpose of this test was to determine ability of the grader to operate for one 8-hour shift with out requiring additional fuel.

Information recorded included factory specification on consumption, factory specification on tank capacity, hourmeter check, amount of fuel supplied, and whether or not eight hours operation was obtained from a full tank.

VIII. REMOVAL OF WINDOWS, DOORS AND CAB

The object was to determine the ease with which doors, windows (windshield) and cab could be removed.

The test consisted of determining if windows, doors and cab were designed for removal, and estimating the time necessary for each operation. The major portion of data were obtained from Forest Service shop personnel and manufacturers.

IX. LIGHTS

The purpose of this test was to determine the adequacy of lights for night operation and travel.

Intensity of the lights was measured by a Weston meter at a distance of three feet. The source of electricity; whether generator, battery or magneto, was recorded. The location of lights, provision for adjustment, and adequacy of protection were noted.

X. ENGINE STARTING

The purpose of these observations was to determine the ability of the engine to start under field conditions.

Time for at least four different starts was determined by a stop watch. Temperature, humidity, whether the engine was hot or cold, type of starting and factory recommended sequence were recorded.

XI. OPERATION OF CONTROLS

The purpose of this test was to determine the adequacy of grader controls.

Information obtained included accessibility, response, ability to vary speed of control action, operation of any two controls at one time, and ease of gear shifting.

XII. TURNING RADIUS

It was desired (1) to determine the minimum circle in which the grader could turn, both right and left, and the road width necessary to do so, and (2) to determine the ability of the grader to turn by backing around in confined areas.

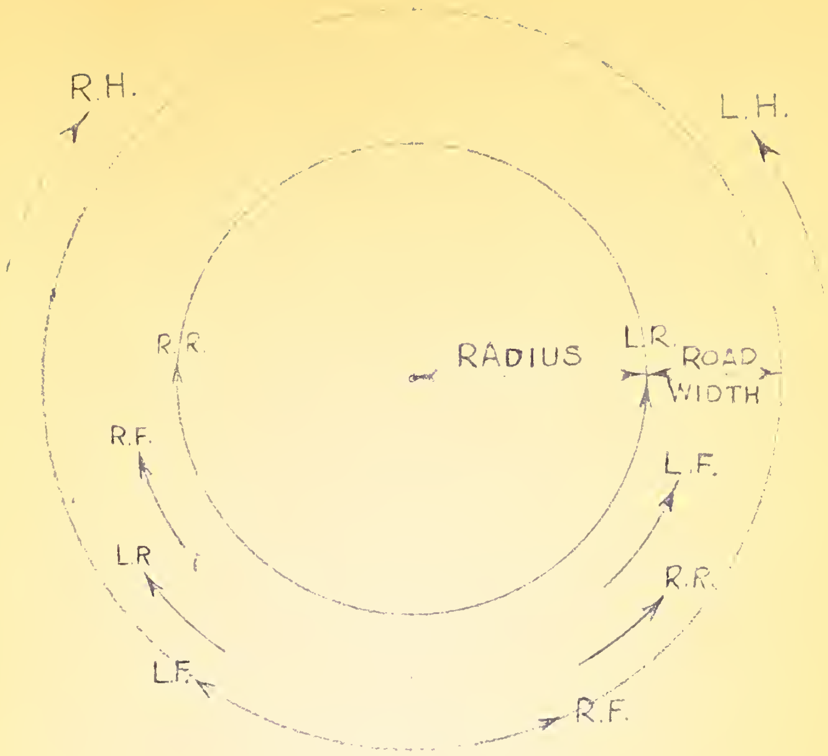
(1) The grader was turned to maximum, and driven to complete a 360° circle, in both right and left direction. The average diameter across the inside tracks was determined by a series of cross-diameter measurements from which the radii were computed.

A second set of measurements was taken across the tracks made in the turning process, and the average taken as the road width necessary for the minimum turn. (Refer to Fig. 2 for sketch.)

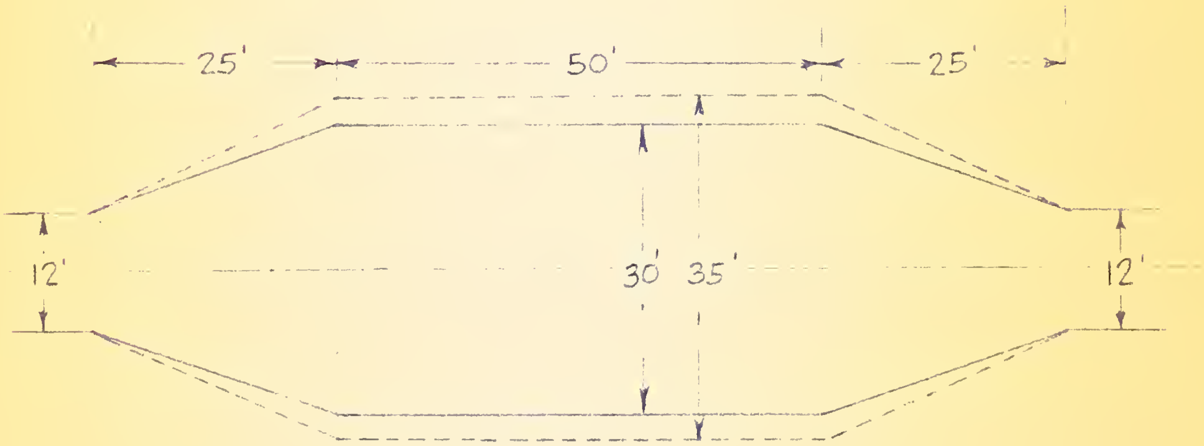
(2) A test area, simulating a "turnout" on a mountain road, was sketched on a paved area with chalk. The road width approach was 12 feet, tapering to 30 feet at a distance of 25 feet. The 30-foot section extended for a distance of 50 feet.

Operators were allowed to practice on the site so that only maneuverability of the machine was reflected in the test.

The object was to enter the area, turn around with the minimum number of backups, and drive out, keeping within perpendicular limits as designated by the sketched lines. A second set of lines was drawn with a 12-foot road and 35-foot turnout. Separate tests were conducted and results recorded for the 30-foot and the 35-foot width sections. (Refer to Fig. 2 for sketch.)



TURNING RADIUS TEST



TURN AROUND TEST

FIG. 2

XIII. BRAKE TEST

The purpose of this test was to determine the ability of the brakes to stop the grader on steep grades and highways.

(a) A hill was stripped of brush and prepared to a compact surface, with grades up to 49%. Graders were required to be stopped by foot brakes and emergency brakes on the steepest part of the hill. Actual roll forward and backward after brakes were applied was measured. Maximum grade on which brakes would hold, both uphill and downhill, was recorded.

Further information noted on both foot brake and parking brake was - location of drums as to 2-wheel, 4-wheel or driveshaft; whether mechanical, hydraulic or electric; provision for holding, and ease of adjustment.

(b) As an additional check on braking ability of the grader, brake tests were made on level pavement, using the AAA brake tester, (Refer Fig. 1 Appendix.) The grader was paced by a car to determine speed of travel, and braking distances for three runs were averaged.

XIV. WALKING TEST

This test was divided into two parts, the first conducted on a paved highway and the second on a truck trail.

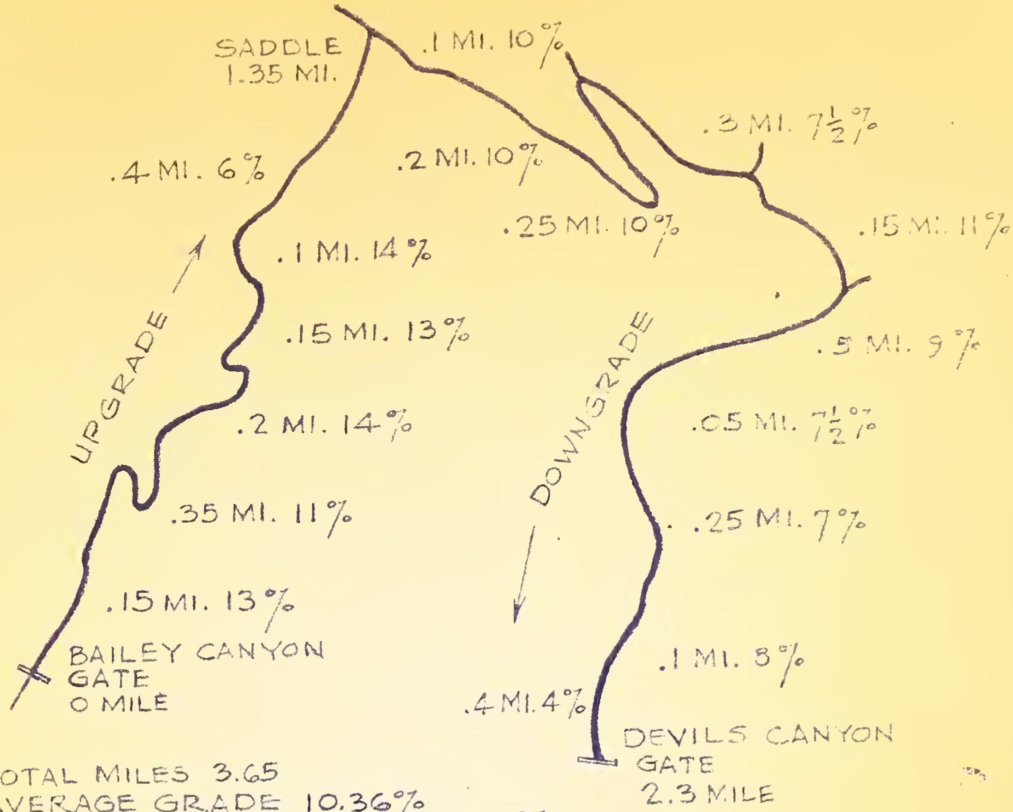
#1. The object in conducting this test was to determine the speed with which the grader could safely travel the highways.

The test was conducted over a measured course, starting from the Triangle Gravel Pit scales, where the official weights were determined, and terminated at the campground at Devil's Canyon, a distance of 6.1 miles. Time was recorded by a stop watch. Machines were run at governed engine speed. See Fig. 3 for map of route.

#2. The purpose of this test was to determine the ability of the grader to safely travel a measured truck trail which would tax the maneuverability of the grader on curves, as well as the maximum power of the engine.

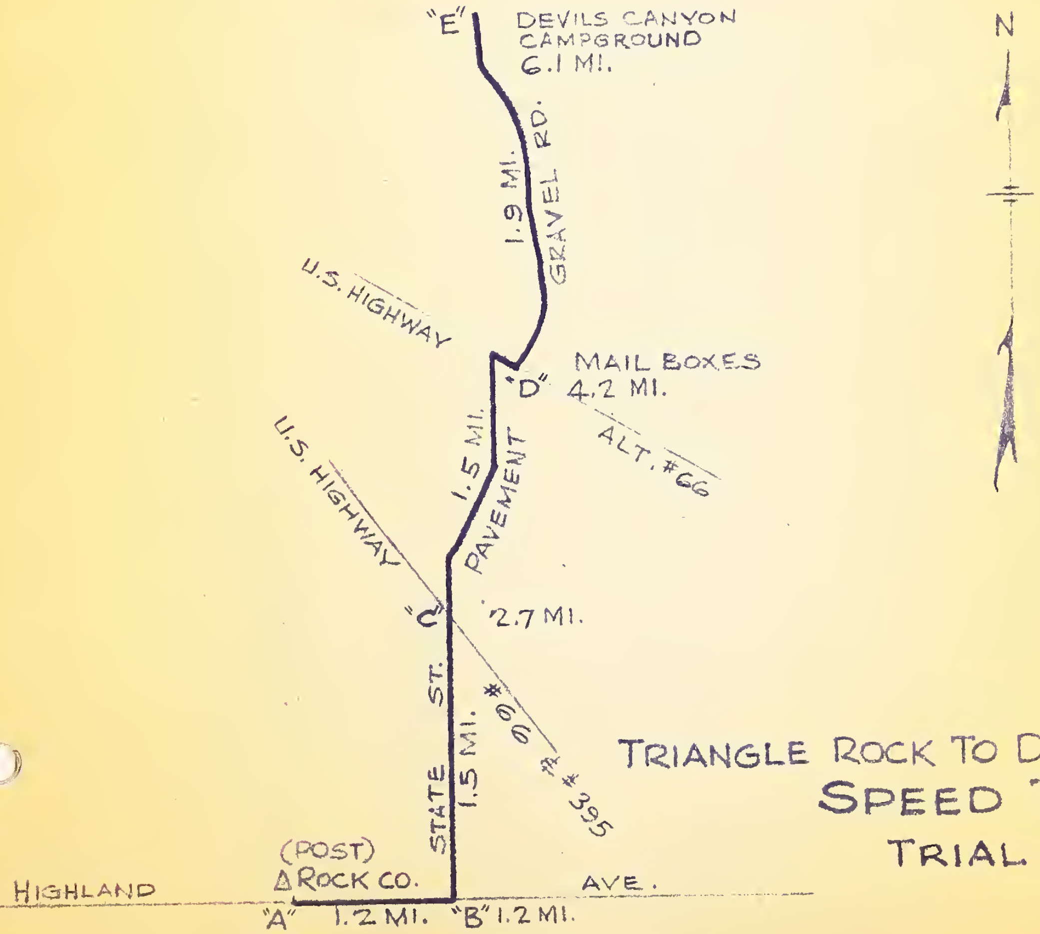
The course started at the Bailey Canyon gate, upgrade to the saddle at the junction of Devil's Canyon truck trail, thence downgrade to Devil's Canyon gate, a distance of 3.65 miles.

Data recorded were time for uphill and downhill trips, grades, and road condition. See Fig. 3 for map of route.



TOTAL MILES 3.65
AVERAGE GRADE 10.36%
1.35 MILES UPGRADE (AV. 11.83 %
2.30 MILES DOWNGRADE (AV. 8.89 %
1 CURVE LESS THAN 35' RADIUS

BAILEY CANYON WALKING TEST -TRIAL 2



TRIANGLE ROCK TO DEVILS CANYON
SPEED TEST
TRIAL 1

FIG. 3

XV. BREAKDOWNS

While not in the form of a test, an informational list was set up as follows: breakdowns, description of breakdowns, photographic record of each, cause (whether design weakness or accident), facilities to repair, availability of parts, and time lost.

XVI. FINAL CHECK

After the grader had been put through the field tests of Section 2, it was returned to the "flat land" slab, thoroughly cleaned and carefully examined for all cracks, breaks and bends which were not evident as definite breakdowns. Each defect was described and photographed for permanent record. Pictures were taken of the tires to record wear and injuries.

DESCRIPTION OF TESTS

Section 2

Field Test

Field performance tests were as follows:

I. <u>SLIDE REMOVAL</u>

The purpose of the test was to observe the ability of graders to surmount obstacles, such as slides commonly encountered in road maintenance.

Slides occur frequently on roads in steep terrain. If the motor patrol can handle the occasional slide and thus save importing a bulldozer, a considerable saving will result.

A slide of designed shape comprising approximately 125 cubic yards was built by a tractor, avoiding compaction of material as much as possible. Dirt was allowed to accumulate on the downgrade (or approach) side at its natural angle of repose, which was approximately 70%. Boundaries were established by means of stakes simulating a perpendicular bank beyond which a wheel under power was not permitted. Refer to Fig. 4.

Fig. 4. Test Slide

DESCRIPTION OF TESTS

Section 3

Field Tests

[illegible]

1. [illegible]

The purpose of the test was to [illegible] the stability of [illegible]

Slides occur frequently on roads in steep terrain. If the [illegible] slide [illegible] will result.

A [illegible] roads [illegible] built on a [illegible] shown in Fig. 4.

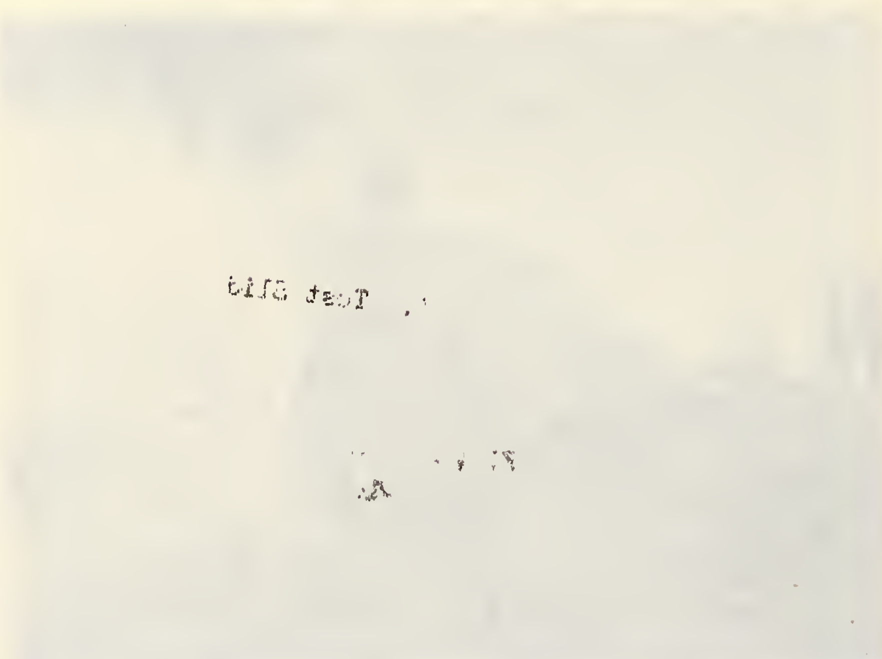


Fig. 4. Test Slide

The test machine was required to climb over the slide in order to be in a position to attack the dirt removal task on a downhill basis.

Test conditions were recorded by still shots and progress during the test by movies. Information recorded consisted of - size of slide and time required to climb over, operator sequence and method of attack.

Since more than one machine was tested at this site, after the machine surmounted the slide, no further dirt was removed. The slide was then reconstructed to original size and shape.

II. IN-CURVE

The purpose of the test was to measure the ability of the grader to maneuver on a short radius in-curve.

Conditions of the test: The situation simulated was the wash-out on a canyon crossing, the outer portion of the road being completely gone and the inner portion defined by vertical walls. It was required that the grader was required to travel the curve, using the minimum road width. See Fig. 5 for details and sketch of test layout.

This condition results frequently after severe storms in rugged country. Ability of a particular machine to handle these situations would save much expense in importing a bull dozer for the operation.

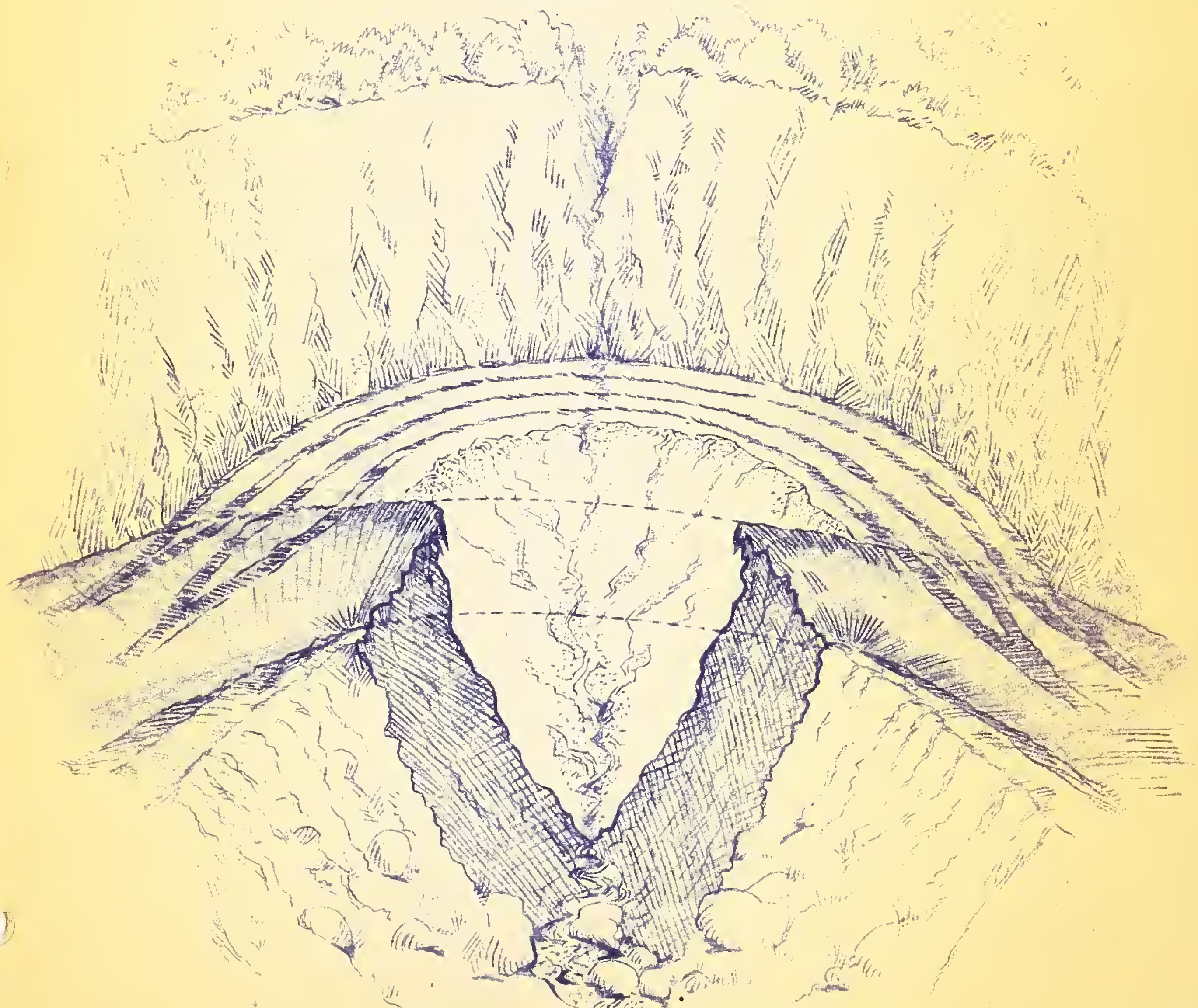
Performance was recorded by use of movies and still pictures. The maximum width of road needed as measured from the inside tire track to the simulated perpendicular wall was recorded.

Since ability of operator affects the time required, re-runs were allowed if operator thought he could improve the performance. Regardless of time consumed, operator ability was evaluated in an attempt to determine machine performance, analyzing reasons for such.

III. GRADING OF DIPS

The life and useability of a road depends to a considerable extent upon the proper functioning of the drainage system. Grading of dips is one of the most important operations of a grader on roads where intercepting drainage dips are used.

INCURVE



SIMULATED CONDITION

FIG. 5

The construction and maintenance of dips involves several of the functioning parts of a motor patrol. A dip consists of an involute curve, descending on an increasing vertical curve with an increasing outslope, until the depression if reached. The bottom of this depression is placed at an angle of 45 degrees to the center line of the road. The profile then rises rapidly for a distance of 15 feet to a summit, also at an angle of 45 degrees to the road center line, then returns to the normal road profile in a second distance of 15 feet. Refer to Fig. 6 for sketch.

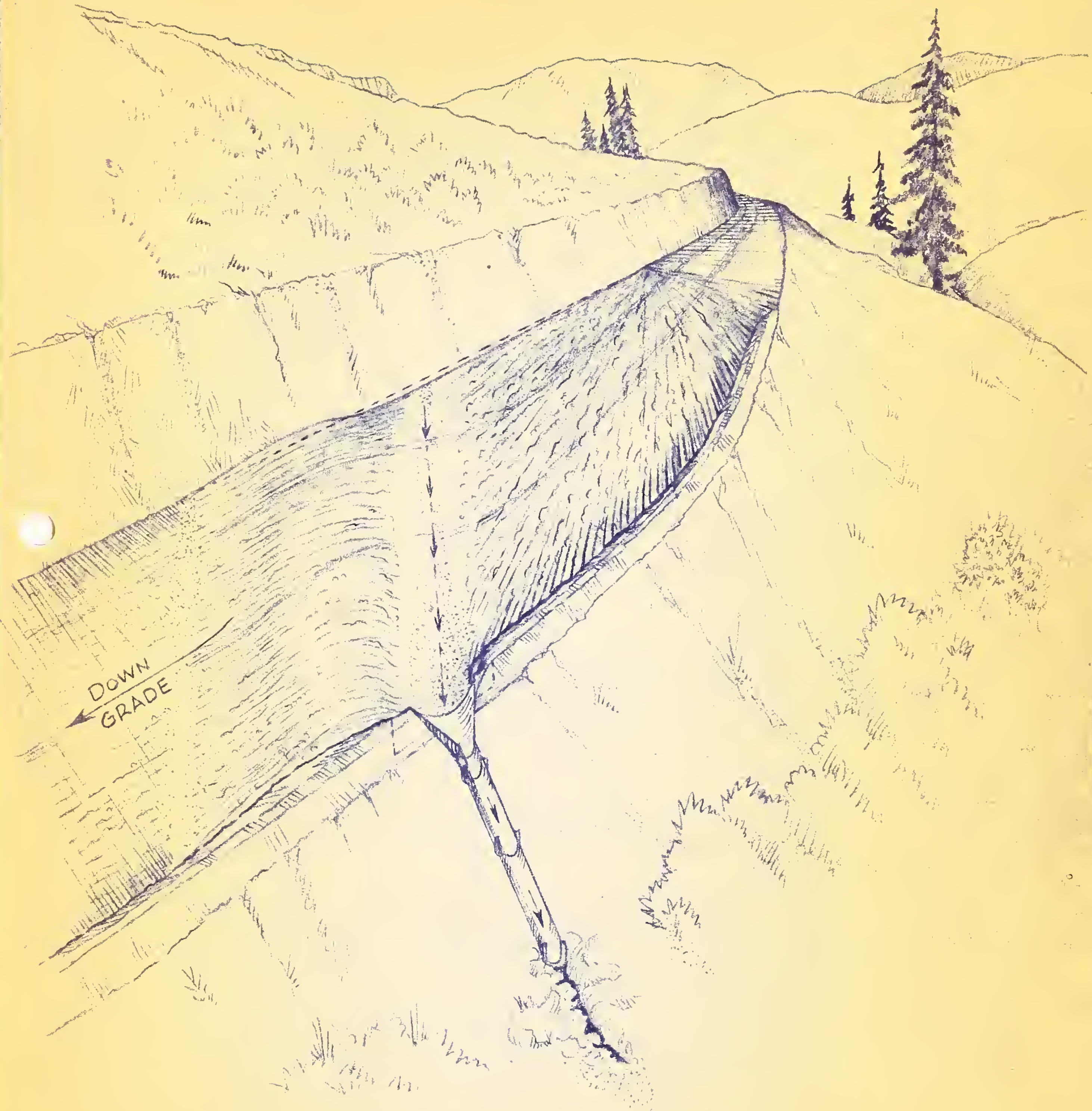
To construct or maintain a dip requires blade manipulation both above and below the plane of the base of the grader wheels. It also requires blade manipulation in a vertical plane to take care of the increasing outslope and also in a horizontal plane to take care of the changing angle of the outslope. This second manipulation is usually handled by steering.

A. New Construction. Conditions: Operator practiced with grader until he was familiar with operation of machine and also the technique of tip construction. Stakes were set indicating beginning of cut, bottom of dip on a 45° angle and termination of berm. Operator was allowed as many passes as was necessary to construct to the proper standard as required by road foreman, who was judging this test.

   Still pictures were taken at side before operation and after, and movies taken during operation for the purpose of analyzing maneuverability of the blade. Information recorded was - location, material, difficulties, operational sequence, time, soil moisture and foreman's rating of completed job.

B. Maintenance of Dips. Existing dips were selected which were in need of reshaping and sluff removal. Motion pictures of operation were taken for analyzing blade response to controls and the ability of the blade to follow an existing profile. At the same time observations were made to determine if the lift mechanism range was adequate for below grade extension while possessing sufficient lift above grade to complete the operation.

   Still pictures before and after were taken. Location, grade, road width, material, difficulties and reasons, operational sequence, time, soil moisture, blade response and control were recorded.



INTERCEPTING DIP

FIG. 6

IV. DITCHING

The purpose of this test was to determine the ability of the machine to function under difficult conditions involving extremely heavy work. The operation involved the use of the blade and scarifier in cutting dirt and rock and in removing large boulders by undercutting and pushing, and the blade and blade control mechanism in finish grading at the end of the operation. It also tested the ability of the machine to provide traction while working on a slope and pushing material uphill. The general toughness of the whole operation was a test of the stamina of the machine.

An area, 200 feet long and 32 feet wide, which was high in rock and boulder content, was selected. Test consisted of digging a 200-foot ditch on a 6% slope similar to shoulder construction on one side of a highway. The vertical depth of the ditch was 3 feet with cut bank on a 3/4-to-1 slope. The distance from the ditch line to the shoulder was 16 feet and constructed on approximately a 4:1 slope. All material was side cast beyond the 16 foot width, or beyond the 200 foot end limits. Operators were allowed to use blade and scarifier.

Information obtained was - location, grade, side slope, material, depth, width, distance, time, and appearance of the finished job. Still pictures before and after were taken, also movies of interesting or unusual incidents.

V. SCARIFYING

The purpose of the test was to determine the ability of the grader to loosen imbedded rock and to do normal scarifying work. Essentially, the test was for the purpose of bringing out the structural ability of the unit to do this kind of work under severe conditions.

This operation is very important. It is required in maintaining road material or a travelable surface on all roads, and is particularly needed after heavy storms.

After completion of the rough shaping of the ditch (Test No. IV), the inside slope area containing numerous imbedded rocks, was used for this test. Information recorded was - location, grade, width of scarifier swath, material, soil moisture, number of teeth used, depth scarified, time, operational sequence, operator reaction, failures, and time required to install teeth for operation. Time element was not important except to require operation at a reasonable speed. Still shots, before and after, and movies were taken.

VI. BANK SLOPING

The purpose of this test was to determine the ability of the graders to side-slope banks at any required slope from $1\frac{1}{2}$-to-1 to 1/4-to-1.

This operation involved the use and adjustment of the control arms, the use of the circle, and general manipulation of the circle and arms assembly.

Sections of roads 500 geet long were selected in which banks at least 10 feet high existed, and included in-curves, out-curves and tangents.

Information recorded was - location, grade, material, distance, time, maximum height of cut, analysis of finished job, difficulties, and operator reaction. Still shots were taked of grader in position, and of road before, during, and after. Short movie sequences were taken to record the operation.

Bank sloping on Forest-Service work is done largely on reconstruction or heavy maintenance work. Although it does not involve a very high percentage of total volume, the occasions of use require a highly maneuverable blade assembly.

VII. DRIFTING

The purpose of this test was to determine the ability of the grader to end-haul material. The operation involves the size, design and pitch of the blade controls.

Drifting is required continually in normal maintenance operations to remove slides, fill washouts, and restore surfacing.

Material for drifting operation was taken from a low cut bank extending 100 feet, moved across a 25-foot area, and placed in an area 75 feet long and 12 feet wide, to a depth of .6 of a foot, forming a finished road bed. At the end of each pass, grader with blade lifted returned to the far end of cut bank section.

Data collected included - location, distance, grade, material, angle of blade, pitch of blade, estimated yardage, material lost or picked up enroute, time, and operator reaction.

Time element was very important in this test since it reflected balance of power and blade size, ease and dexterity of blade movement and time consumed in shifting gears.

Still pictures were taken to show before and after operation, also movies to show dirt movement on blade, and amount of material being moved.

VIII. HORIZONTAL MOVEMENT OF WINDROW

The purpose of this test was to determine the ability of the machine to move a windrow of dirt laterally. It involved the size, shape and pitch of the blade, the tractive ability of the machine, and the functioning of the blade control mechanism.

This operation is used in all road mix oiling work and in construction of roads on flat terrain.

A section of road 1300 feet long, with an average grade of 9%, was designated as the test area. A large windrow was formed on one side of the road, and measurements made from established reference points. The grader in four passes was required to move as much material as possible to the opposite side of the road, forming a more or less uniform windrow. Lateral movement of dirt was determined by measurements taken at the reference points, and total yardage figured from cross section measurements taken every 100 feet. The elapsed time for the operation was recorded.

IX. SHAPING BERMS

The purpose of the test was to determine ability of the grader to form a berm 18" high with side slopes $1\frac{1}{2}$:1. This operation is of great importance on all roads using berms as a drainage control feature. This includes most of the road mileage in the California Region.

A section of road between 300 and 500 feet in length was selected and material in existing berm was spread over the road bed. Three passes were then made, ending up with the material forming a uniform berm on the outer edge of road.

Information recorded was - location, grade, material, distance and time. Still shots before, during, and after operation were taken.

X. HILL CLIMB

The purpose of the test was to determine the ability of the machine to climb grades up to 50% in both forward and reverse gears.

The site selected for the test had a runway with an overall length of 300 feet, which started level and gradually sloped up to a maximum of 49%. Graders were required to climb uphill forward and uphill backward, recording percent of grade at the forward point of stalling, if any. The decomposed granite surface of the hill was prepared before each run so no loose material hindered the test.

XI. UPHILL GRADING

The purpose was to determine the ability of the machine to climb uphill and do normal grading at the same time.

Road sections, 500 feet long, in which grades from 10 to 21% existed, were selected. One pass uphill was made.

Information noted was - location, material, soil moisture, grade, time, tendency of machine to drift under load, and appraisal by road foreman as to effectiveness of the work. Still shots before and after, and movies during operation were taken.

XII. ROAD GRADING

The purpose of the test was two-fold; first, to acquaint operator with the three-pass operation in road maintenance and, second, to provide an opportunity for observers to analyze the performance of each grader on a short section of road.

Sections of road 500 feet long were selected which were in need of maintenance, and which included in-curves, out-curves, turnouts and dips.

Operation consisted of three passes: cleaning the ditch of sluff, spreading and removing rocks and smoothing.

Information recorded was - location, grade, road condition as to ruts, amount of sluff, material, soil moisture, distance, time, maneuverability, difficulties, appearance of finished job, and operator's reaction. Still shots before, during, and after operation were taken.

XIII. ROAD MAINTENANCE - LONG SECTION

The purpose of this test was to determine the overall ability of the grader to do all of the important functions of a road maintenance job. These operations include slide and sluff removal, dip maintenance, normal and fine grading, berm construction, and drifting. Bank sloping was not included. Operation was up and down hill and around minimum radius curves (under 35 feet), and involved the use of all grader controls.

This work is the primary purpose for which motor patrols are purchased and constitutes the larger portion of their use.

Sections of truck trail with grades up to 20% and needing maintenance work, two miles in length, were marked by means of flags. Picture stations were marked for the purpose of before and after photographic records which would depict the different functions common to the operations of rock removal, sluff removal, dip cleaning and shaping, and fine grading. Three passes were required.

Information recorded was - location, material, distance, time, amount of work to do in rock, sluff removal, number of dips to shape, and number of minimum curves.

Appearance of the finished job was appraised by engineers and road foremen.

Fine Grading

On the two mile maintenance section an area suitable for fine grading was selected where no appreciable amount of rock was present.

Results of the operation were carefully analyzed for absolute control of the blade, since this test was considered as a measure of the ability of the grader to handle surfacing operations.

Still pictures before and after were taken to indicate the degree of improvement resulting from the operation.

TEST RESULTS & COMPARATIVE DATA

To facilitate comparison and to conveniently tabulate the various date obtained from the test, Table I, Comparative Data, has been prepared.

The date recorded in column one (1) are taken from the manufacturers' published specification sheet and cover the standard production model only.

In column two (2), are summarized the data taken from the "flat land" and "field test" sections of the report. Discrepancies in this column from the manufacturers' ratings as shown in column one (1) may be attributed to definition or deviation from standard on the test machine. Where considered necessary, deviations are discussed under the Discussion of Test Results.

In columns three (3) and four (4) are the data of other graders tested in this class. The intent here is to show the maximum and minimum of the other data collected. It should be noted that the maximum as shown does not necessarily infer the best, particularly where time is involved. Constant appraisal of the item under consideration will be necessary to properly evaluate the tabulated results.

TABLE I

COMPARATIVE DATA

Flatland Tests

Item	Mfr. Spec. Std. Machine (1)	A.W. 99-H Test Mach. (2)	Other Graders Tested Maximum (3)	Other Graders Tested Minimum (4)
WEIGHT				
Weight, total	22,500	22,560	27,930	24,500
Weight on front whls.	9,790	9,350	8,630	7,370
Weight on rear wheels	12,710	13,150	19,300	17,130
Blade pressure	18,500	18,520	15,460	12,300
Scarifier pressure	11,100	10,460	9,970	8,2[illegible]0
DIMENSIONS				
Length overall	24'-3"	24'-3"	27'-0"	25'-0"
Width overall	7'-10-3/4"	7'-10-3/4"	8'-0"	7'-7 3/4"
Height overall w/cab	10'-1"	10'-1"	10'-8"	9'-8¾"
Height overall w/out cab	8'-8"	8'-8"	8'-0"	6'-10"
Height inside cab	---	73¼"	75½"	69"
Wheelbase	18'-8"	18'-8"	19'-7"	18'-9"
Tread, front, c. to c. of tires.	---	79½"	83¼"	79"
Tread, rear, c. to c. of tires.	---	79½"	82"	78½"
SPEEDS				
Min. forward mph	1.7	---	2.6	2.[illegible]
Max. forward mph	15.0	---	25.2	16.63
Min. reverse mph	1.74	---	3.7	2.7
Max. reverse mph	5.87	---	6.13	4.[illegible]
Number forward	6	6	8	5
Number reverse	2	2	3	1
ENGINE				
Brake HP	76	76	113	100
No. of cylinders	4	4	6	4
RPM - Governed max.	1,400	1,555	1,990	1,660
CAPACITIES				
Fuel tank (gals.)	58	58	60	45
Cooling system (gals.)	14	14	20	6½
Crankcase (qts.)	16	16	23	16
TIRES				
Size, front	14.00-20	14.00-20	14.00-24	13.00-24
Size, rear	14.00-20	14.00-20	14.00-24	13.00-24
Ply	14	14	12	8

TABLE I (Continued)

COMPARATIVE DATA

Flatland Tests

Items	Mfr. Spec. Std. Machine (1)	A.W. 99-H Test Mach. (2)	Other Graders Tested: Maximum (3)	Other Graders Tested: Minimum (4)
BLADE ASSEMBLY				
Moldboard - length, width, thickness	13'x22½"x3/4"	13'x22½"x3/4"	12'x2[illegible]	12'x[illegible]
Blade side shift (Mfr. Rating)	7" power oper.	----	16½"	16½"
Right blade side shift from center position (circle shift)	----	19"	25¼"	16½"
(circle shift & link adj.)	----	19"	38¼"	22"
(circle, links & moldboard adj.)	----	57"	52½"	5[illegible]
Blade lift above ground Sect. 1 - Test E	16"	16"	15½"	14-3/4"
Blade depth below ground Sect. 1 - Test E	---	23½"	10½"	5"
Pitch positions - number for tilting	---	6	15	7
Max. shoulder reach	89½"	88¼"	87"	76½"
Bank slope angle (test conditions 1-C-3)	----	63°	74°	52°
Circle diameter	62'	62"	63"	54"
Degree turn blade w/scar. teeth	----	320°	320°	296°
Degree turn w/o scarifier teeth	----	320°	360°	360°
Lifting speed (Approx.)	---	2.37"/sec.	2.18"/sec.	0.98"/ sec.
SCARIFIER - V TYPE				
Weight	1,300	1,300	1,475	1,314
Swath width	46"	46"	46"	46"
Teeth number	11	11	11	9
Teeth size	1"x3"	1"x3"	1¼"x3½"	1"x3"
Pitch positions	---	1	5	1
Pressure max.	---	10,460	9,970	8,200
WHEEL LEAN				
Max. L	0°	0°	21½°	15½°
Max. R	0°	0°	21½°	11°

TABLE I (Continued)

COMPARATIVE DATA

Flatland Tests

Items	Mfr. Spec. Std. Machine (1)	A.W. 99-H Test Mach. (2)	Other Graders Tested Maximum (3)	Other Graders Tested Minimum (4)
GROUND CLEARANCE				
Behind blade) Wheels Vert.	---	13"	13½"	10-3/8"
Front blade) Wheels Vert.	---	14"	27½"	19-3/8"
Behind blade) Wheels Max. lean	---	---	13½"	10-3/8"
Front blade) Wheels Max. lean	---	---	27"	19"
TURNING				
Turning radius (Inside wheel) R	30'-10"	22'-½"	27'-9"	21'-10"
Turning radius (Inside wheel) L	---	22'-9"	29'-3"	26'-9"
Turn. radius - Av. inside wheel ÷ av. road width	---	30'-6"	41'-2½"	38'-5"
Road width to turn R	---	8'-0"	13'-10"	12'-8"
Road width to turn L	---	8'-2"	13'-4"	12'-9"

TABLE I (Continued)

COMPARATIVE DATA

Field Tests

Items	Mfr. Spec. Std. Machine (1)	A.W. 99-H Test Mach. (2)	Other Graders Tested Maximum (3)	Other Graders Tested Minimum (4)
ROAD WIDTH FOR TURNING - NUMBER OF BACKUPS				
35 Foot Road	---	2	4	2
30 Foot Road	---	3	8	5
DIP CONSTRUCTION (Time)	---	25 M. 23 S.	27M.0 S.	14 M. 36 S.
DITCH CONSTRUCTION (Time)	---	8 H. 58 M.	11 H. 33 M.	8 H. 20 M.
DRIFTING (Cu. Yds./min.)	---	1.1	1.29	0.97
MOVE WINDROW (Cu. Yds. Feet/min.)	---	85.5	149.0	96.5
SLIDE (Climb over min.)	---	50 M. 0 S.	41 M. 0 S.	15 M. 57 S.
INSIDE CURVE				
Road width needed - Av. L & R	---	9'-7½"	19'-11½"	19'-6"
ROAD MAINTENANCE (Miles/Hr.)	---	0.48	0.635	0.51
BRAKE TEST - @ 18 mph	---	15'	38'	19'
Cal. Veh. Code Min.	30'			
WALKING TEST (1)				
Paved highway	4.2 Miles	15.8 mph	24.6 mph	18.3 mph
Dirt highway	1.9 Miles	12.35 "	17.54 "	14.07 "
Total highway	6.1 Miles	14.5 "	19.94 "	17.7 "
WALKING TEST (2)				
Uphill T.T.	1.35 Miles	6.11 mph	6.56 mph	4.49 mph
Downhill T.T.	2.3 Miles	9.13 "	16.24 "	9.69 "
Total T.T.	3.65 Miles	7.70 "	9.98 "	8.27 "

DISCUSSION OF RESULTS

Flatland Tests

WEIGHTS

The weight distribution of the A.W. 99-H in Table I was found to vary considerably in all respects from that of the tandem graders. Table II-A below shows deviation from the average of the tandems.

TABLE II-A

WEIGHTS

	Weights		Distribution - Percent	
	A.W. 99-H	Av. Other Graders	A.W. 99-H	Tandem Machines
Total	22,560	25,558	100	100
Front	9,350	7,695	41.5	30.1
Rear	13,150	17,812	58.4	69.7
Scarifier	10,460	8,922	46.4	34.9
Blade	18,520	13,457	82.2	52.6

It will be noted that the A.W. grader weighed 3,000 pounds less than the average of the other graders. This lack of weight might be judged a handicap for heavy duty work, unless overall design of the grader is considered. Since the entire weight bears on drive wheels, this lack of weight was somewhat compensated for by maximum traction. Although lightest in overall weight, the A.W. had a front wheel weight which exceeded that of all other graders by 1,655 pounds. Such weight distribution on tandem machines would be a distinct disadvantage, but on the A.W. the weight was more evenly distributed on the drivewheels for maximum traction, and the additional weight on the front wheels added to stability.

Weight on rear wheels was decidedly less for the A.W. but this was no handicap for reasons explained above.

More weight could be exerted on the scarifier by the A.W. than by other graders, however, this is a questionable advantage since excessive weight is unnecessary on scarifier teeth.

It will be noted in Table II-A that the A.W. can exert 82.2% of its total weight on the blade, compared to an average of 52.6% for other graders. While it is imperative that sufficient weight be applied to the blade for hard surfaces, it is obvious that there is a limit to the amount of weight which can be utilized and still maintain traction and stability. Consequently, this additional pressure on the blade cannot be considered as an advantage over other graders since they likewise can exert at least half their total weight on the blade.

Proper weight distribution of some graders was questioned several times during field tests. After reviewing the weights of all graders, it was decided that horsepower was a factor to be considered along with weight. In an effort to analyze the relationship between weight and horsepower, a comparison was made between overall weight and horsepower, and also between drivewheel weight and horsepower. Results are tabulated in Table II-B.

TABLE II-B

WEIGHT HORSEPOWER RATIOS

	A.W. 99-H	Other Tandems Maximum	Other Tandems Minimum
Overall Weight	22,560	27,950	25,100
Drivewheel Weight	22,560	19,300	17,600
Horsepower	76	100	113
Total Lbs. / H.P.	296	280	222
Drivewheel Lbs. / H.P.	296	193	156

The ratio of drivewheel weight to horsepower for the A.W. was 296 as compared to a maximum of 193 for the tandems. Since the A.W. was all wheel driven, the ratio between overall weight to horsepower was the same and also the highest. In all of the field operations the A. W. was able to perform with minimum loss of traction or evidence of excessive drifting.

It was noted that two machines were excessive drifters. Computations showed the ratio of overall weight to horsepower of one to be 236 and the other 222. The ratio of drive wheel weight to horsepower for these machines was 165 to 156 respectively.

It is not the intent of this report to determine the ideal weight horsepower ratios, but merely to suggest that this weight power relationship may play an important part in the performance of a grader.

DIMENSIONS

Of all the machines tested, the A.W. 99-H had the least overall length and wheelbase. This was a distinct advantage to grader maneuverability. The vertical clearance inside cab of the A.W. 99-H of 73¼" was above average when compared with other graders. The minimum cab clearance for the group was 69" which was considered inadequate. Height with cab and overall width of the A.W. 99-H was within the range noted for the other graders. Height without cab was 8" more than any other grader.

Size and weights of the A.W. 99-H frame sections appeared adequate and comparable to the average of other graders tested.

SPEEDS

The A.W. 99-H had six speeds forward and two reverse. Gear reduction was such as to provide adequate speed and power for all tests except these involving highway travel. Maximum forward speed of 15 mph, while sufficient for truck trail maintenance, was not thought adequate for moving the grader from job to job. Reverse speeds should be carefully considered as they apply to actual field requirements. Experience would indicate a need for a low speed to be used for backing out of a bad situation, and a much higher speed for backing up rapidly under normal operation when the blade is empty. Selection of gear reduction in the A.W. were evidently made with this in mind, resulting in a low reverse speed of 1.7 mph and a high reverse of 5.87 mph. When compared to a machine which has two reverse speeds of 3.4 and 4.6 mph the advantage of the A.W. is evident.

The comment here applies only to speed and is not intended to cover the transmission as a mechanism for changing speeds. This is discussed elsewhere in the report.

ENGINE

The A.W. 99-H had an International, four cylinder, four stroke cycle diesel engine with a bore of 4-3/4", stroke of $6\frac{1}{2}$", displacement of 460.7 cu. in. and was rated at 76 brake horsepower at a governed speed of 1400 rpm. The engine had a crankcase capacity of 16 qts. and the recommended fuel was commercial diesel. Electric starting was provided with the engine being started on gasoline and shifted to diesel fuel.

I. BLADE OPERATION

A. Operation of Circle. The time required for one cycle of operation of the blade circle on the A.W. 99-H was 1 min. 50 sec. which was next to maximum time for all other graders tested. The minimum for the group of graders with mechanical controls was 40 seconds. A maximum time of 2 min. 19 sec. was required for the other grader equipped with hydraulic controls.

The A.W. 99-H was equipped with a 13-foot blade and had a blade cycle of only 320° due to the fact that the blade at one end failed to clear the scarifier block by $1\frac{1}{2}$". However, this machine could clear both scarifier block and teeth, and complete a 360° cycle when equipped with a 12-foot blade.

B. Locking Devices. The A.W. 99-H was the only machine tested which had a positive circle locking device to prevent shifting of blade under load. Although controlled from the cab, the lock could not be readily released under blade load, and such procedure was not recommended by the manufacturer. Other test graders which had mechanical controls depended upon worm gears and friction drags on the worm gear drives to prevent blade "creep".

Although blade "creep" under load has been experienced on graders by the Forest Service in the past, there was no evidence of its existance on mechanically controlled graders tested. It was concluded by test observers that means other than that used by the A.W. 99-H to lock the circle would be desirable. But in all instances, and regardless of locking method used, adequate provision to eliminate blade "creep" must be provided.

C. <u>Bank Sloping Positions</u>. The A.W. 99-H, like all other machines tested, had no special attachments for bank sloping. This unit had the advantage over all other graders tested in its ability to attain bank sloping positions directly from normal flat blade position, all controlled from within the cab. Side shift of blade on circle was also cab controlled. This increased blade maneuverability and efficiency since it was not necessary to stop the machine and to change linkage or manually side shift the blade on the circle, as was normally required for all other graders performing in similar circumstances.

In this test, the blade on the A.W. could be readily shifted to all bank sloping positions required.

The following tabulation, Table III, shows the height of the blade tip and the position of the heel of the blade for various bank slope positions, together with maximum and minimum measurements for other machines tested.

TABLE III

Bank Slope Blade Positions

Bank Slope	Angle		A.W. 99-H	Other Machines Tested Maximum	Minimum
1½:1	34°	Height of tip above ground	32"	65"	32½"
		" " heel " "	0	0	0
		Distance heel inside ref line	0	24"	0
		" " outside " "	0	0	0
1:1	45°	Height of tip above ground	75½"	81"	49"
		" " heel " "	0	0	0
		Distance heel inside ref line	0	10½"	0
		" " outside " "	0	0	0
3/4:1	53°	Height of tip above ground	82½"	112"	84"
		" " heel " "	0	0	0
		Distance heel inside ref line	0	6½"	0
		" " outside " "	6"	0	0
½:1	63°	Height of tip above ground	114"	123"	84"
		" " heel " "	0	0	0
		Distance heel inside ref line	0	0	0
		" " outside " "	15½"	14½"	0
¼:1	76°	Height of tip above ground	76½"	138½"	109"
		" " heel " "	0	6½"	0
		Distance heel inside ref line	0	0	0
		" " outside " "	23-3/4"	17½"	12"

Photographs Fig. 7 and 8 show bank slope angle for 1:1 and $\frac{1}{2}$:1 slopes.

Fig. 7. 1:1 Bank Slope Angle

Fig. 8. $\frac{1}{2}$:1 Bank Slope Angle

D. <u>Side Shift</u>. With the blade set in center normal operating position, it was shifted 19" to the right at ground level by means of the lift and lateral controls. This was with the lateral linkage set for right hand operating position. With the lateral link set for left hand operating position, the blade was shifted an equal distance to the left. This compared with a minimum of 16½" and a maximum of 25¼" for the other machines tested.

It should be noted here that although 19" was the maximum sideshift distance for the A.W. 99-H under conditions stipulated for this phase of the test, an actual additional sideshift of 38" was readily available through power control from the cab. This grader was the only one tested which had this feature.

Fig. 9. Side Shift of Blade

The time for the shift from center position to maximum right and return to center was 42 seconds, as compared with the minimum of 49 seconds and maximum of 66 seconds for the other machines. Due to the different distances, these time figures were reduced to shift in inches per second and are shown in the following table.

TABLE IV

Blade Side Shift

With Blade Centered on Circle	A.W. 99-H	Other Machines Tested	
		Maximum	Minimum
Distance Right	19"	25¼"	16½"
Shift Inches per Second	.91	.98	.61

The number of linkages for blade control of the A.W. (and points of wear) were at a minimum.

Linkage ball studs were given particular attention on all units to determine attaching method (welded solid, cast integral with a relative part, detachable by means of a threaded shank, etc.) On the A.W. 99-H these studs were integrally attached by welding, wherever possible to do so, thereby keeping wear-points to a minimum. It appears desirable that these particular parts be firmly attached. Replacement of these parts is usually a minimum requirement, and experience with the detachable type has indicated disadvantages which can be overcome by integral attachment.

On the machines tested there were three methods of blade side shift on circle (1) power ram, (2) unbolting and rebolting blade on blade beams, and (3) blade slide. Time for blade shifting on machines where blade was unbolted, shifted and rebolted, averaged 9 minutes 9 seconds. Machines using slide mechanism averaged more than 20 minutes. Power ram time was less than 30 seconds.

E. Blade Lift. The maximum lift of blade above ground, drop below ground, angle of lift right and left with blade centered, and the clearance between blade cutting edge and bottom of circle are given in the comparison Table V.

TABLE V

Blade Lift

With Blade in Normal Operating Position	A.W. 99-H	Other Machines Tested Maximum	Other Machines Tested Minimum
Max. Lift above ground	16"	15½"	14-3/4"
Time for max. lift	6-3/4 Sec.	15 Sec.	7 Sec.
Rate of lift (in. per sec.)	2.37"	2.18"	.98"
Max. drop below ground	23½"	10½"	5"
Clearance blade cutting edge to circle	28½"	27-3/4"	24½"
Max. angle right	8½°	15½°	8°
Max. angle left	8½°	13½°	8°

In the above group of operations, with exception of maximum right and left angles, the A.W. 99-H was above average when compared to the other machines. Total blade lift and lower range (controlled wholly from cab) was 39½" for this machine as compared to a maximum of 25-3/4" for any other grader tested.

With regard to exception noted for right and left angles, the $8\frac{1}{2}^{o}$ angles recorded were next to the minimum for any machine tested. It was recognized that the 13 foot blade on this unit decreased the maximum angles which could have been obtained with a 12 foot blade. Photograph, Fig. 10, shows blade lift angle from centered position.

Fig. 10. Blade lift angle from centered position.

Note: The test method and definition of the angles referred to here are explained in the forepart of this report under Flatland Tests, Blade Lift.

F. <u>Blade Reverse.</u> This function was accomplished by the A.W. 99-H without difficulty. However, since the 13 foot blade was not full revolving, the angle of turn in going from one position to another was sometimes greater than that of machines having full revolving blades. For example when going forward with the blade set for right hand operation at 45^{o} and casting material to the left of the machine, the blade had to be turned through 270^{o} to grade in reverse and cast material to the same side. For machines having full revolving blade the angle of turn to do the same work would be only 90^{o}.

G. Blade Pitch Positions. The comparative table of pitch positions and angle of pitch is given in Table VI.

TABLE VI

Blade Pitch

	A.W. 99-H	Other Machines Tested	
		Maximum	Minimum
Pitch Forward	+ 29°	+ 43½°	+ 27½°
Pitch Rear	+ 9°	- 17 °	+ 1 °
Pitch Positions	6	15	7

The angle of pitch and number of pitch positions of the moldboard on the A.W. 99-H were less than that of other graders tested. Pitch angle range and positions while comparatively limited did not present any noticeable difficulties during the tests.

H. Visibility. Visibility of wheels and blade is of special importance in Forest Service operations where steep grades, narrow roads, and short radius curves are prevalent. None of the units tested had complete visibility, since all had mechanisms that partially obstructed the operator's view of either blade or wheels. It was the concensus of observers that the A.W. 99-H rated second best of the five machines tested. Refer to photographs Figs. 11 and 12 for visibility views.

II. WHEEL LEAN

The A. W. 99-H does not use leaning wheels. As a means of compensating for blade side thrust, the A.W. 99-H employs the use of four wheel drive and front and rear axle steer to position the grader to maximum advantage. Tests showed this method to be adequate except where road width was restricted.

III. GROUND CLEARANCE

Ground clearances for the A.W. 99-H are listed in Table VII with maximum and minimum values for the tandem graders tested.

Fig. 11. Visibility from a sitting position

Fig. 12. Visibility from a standing position

TABLE VII

Ground Clearance

	A.W. 99-H	Other Machines Tested Maximum	Other Machines Tested Minimum
Wheels Vert. Behind Blade	13"	13½"	10-3/8"
Front of Blade	14"	27½"	19-3/8"

Behind blade ground clearance for the A.W. 99-H compared favorably with the tandem machines. Ground clearance in front of blade on this unit measured 14", which was considerably less than for tandem machines. Due to ability to steer the rear wheels, the front end could be offset so that it was unnecessary to straddle a windrow or large obstacle to be moved. In general this offset feature is adequate, however, narrow roads would prevent maneuvering in this manner.

IV. FRONT AXLE TREAD

Test data are shown in Table VIII.

TABLE VIII

Front Axle Tread

A.W. 99-H	Maximum Other	Minimum Other
79½"	83¼"	79"

The A.W. 99-H front axle tread rated closely with the minimum for any unit tested.

There were no operational difficulties noted during the tests which might be attributed directly to excessive width of tread.

V. SERVICING REQUIREMENTS

Records were kept of the fuel used by all of the machines tested. The table below shows fuel used and amount consumed per hour for the test period.

TABLE IX

Fuel Consumption

	A.W. 99-H	Maximum Other	Minimum Other
Fuel - gal.	209	272	209
Gal./ Hr.	2.61	3.76	2.41

Although recorded and tabulated, these data cannot be taken as true indications of consumption because of the uncertainty as to exact amounts of idling and full throttle times. The fuel consumption for the A.W. 99-H, as noted in Table IX, was higher than expected, possibly for the reason noted.

The total number of service points and the number requiring daily, weekly and monthly checks are shown in Table X.

TABLE X

Service Data

	A.W. 99-H	Grader A	Grader B	Grader C	Grader D
Total Serv. Pts.	103	112	101	114	70
No. Daily Serv.	46	4	92	63	40
No. Weekly Serv.	34	77 (20 hrs.)	6	50	9
Other	23	31	3	1	21
Total Points to Serv. During Wk.	264	174	466	365	209

The data in the above table is not exactly in accord with the manufacturer's recommendations. This is primarily because of the difficulty in determining the actual lube points from the instructions furnished, and also because of the use of other than daily and weekly periods. It does, however, represent the observer's best estimate of service and effort.

While the conclusions that could be drawn from the table may be considered insignificant, the problem of lubricating machines is important. Each point requiring lubrication is a potential source of trouble if not serviced. Time for servicing, particularly daily service, is most often lost time from production.

On the basis of the tabulations made, the A.W. 99-H was considered average in the number of points requiring weekly accumulative service.

VI. TIRES AND RIMS

Tires as furnished on the A.W. 99-H were Firestone 14.00x20-14 ply, which was the heaviest ply used in the test. Inspection upon completion of the test showed wear on tires to be negligible.

Notes taken from the field data are listed below for comparison.

A.W. 99-H	- Wear - "Negligible", Breaks - "No breaks."
Grader A	- Wear - "Tires badly worn and cut."
Grader B	- Wear - "Negligible", Breaks - "None"
Grader C	- Wear - "Negligible", Breaks - "None" (1 small cut ((sidewall)) R.R. Tandem)
Grader D	- Wear - "Very little wear", Breaks - "None some rock cuts - not serious."

No trouble was experienced with the drop center taper head rims used on the A.W. 99-H.

VII. TANK CAPACITY

Comparative tank capacities are shown in Table XI.

TABLE XI

Fuel Tank Capacities

A.W. 99-H	Maximum Other	Minimum Other
58 Gal.	60 Gal.	45 Gal.

Tank capacity of the A.W. was sufficient for more than 8 hours of operation. Based on the tests and operator reaction, this was considered adequate.

VIII. REMOVAL OF WINDOWS, DOORS AND CAB

The time required to remove the cab on the A.W. 99-H was estimated to be 4 hours. Doors, windshield, and rear cab glass could be removed in about one hour.

The problem in connection with cab, door, and window removal was almost the same for all graders, with the possible exception of one tandem which used hinge pins to facilitate removal of doors and windows.

All cabs could best be handled with shop facilities and required considerable removal of bolts to effect dismounting.

IX. LIGHTS

Intensity of lights, measured with a Weston meter three feet from the light source, varied from slightly under 800 to 1200 for the five graders tested. The value for the A.W. 99-H was 900. From the limited testing of lights on all graders, it was concluded that all were adequate for travel illumination, but possibly would not comply with State Highway codes in all instances.

Lights on the A.W. 99-H were mounted on the lift ram supports, although optional provision was made for mounting near top of cab.

Data recorded for the lights as furnished with the A.W. 99-H are tabulated below:

Location	- On lift ram supports
Number	- Two
Weston Intensity	- 900
Protected	- No
Adjustable	- Yes
Illuminate blade	- Not as mounted
Adequate for highway travel	- Yes

The observers agreed that in future consideration of lights for motor graders, more emphasis should be placed on adjustable mountings which will permit night illumination of the blade, protected lens on forward lights, and some provision for backup lighting.

X. ENGINE STARTING

The average time and temperature for four cold starts is shown in Table XII.

TABLE XII

Engine Starts

	A.W. 99-H	Maximum Other	Minimum Other
Average Time	70 Sec.	133 Sec.	10 Sec.
Average Temp.	46°	59°	42°

No difficulty was experienced in starting the A.W. 99-H engine at any time during the test. The average starting time for this machine was considered satisfactory.

XI. OPERATION OF CONTROLS

The discussion here is confined only to the actual controls as contained in the cab.

Comparison of cab controls on the various graders tested indicated certain apparent good and bad features. Accessibility and ease of control manipulation were given particular attention as to their affect on operator fatigue.

Controls on the A.W. 99-H were considered by observers to be adequate and satisfactory, with exception of operation of the blade circle lock. This latter control was reported as awkward to operate and requiring considerable practice for satisfactory operation.

The A.W. 99-H grader had a steering lever instead of a wheel, which allowed accessibility to hand controls normally restricted by a full wheel.

XII. TURNING RADIUS

(1) - Turning radius was established as the radius of the inside track of a complete turn. The distance between inside and outside tracks was taken as the required road width for the turn. Table XIII gives turning radius and road width for the A.W. as well as the maximum and minimum values for other graders tested.

TABLE XIII

Turning Radius

	A.W. 99-H	Maximum Other	Minimum Other
Turn. Radius - Right	22'-½"	27'-9"	21'-10"
Turn. Radius - Left	22'-9"	29'-3"	26'-9"
Average Road Width	8'-1"	13'-5½"	12'-9½"

The A.W. 99-H turning radius was slightly in excess of the minimum for other machines, or 22'-½" compared to 21'-10". This data, although accurately recorded, is misleading. The machine for which the minimum was recorded had an unbalanced turning radius right and left as follows: Right: 21'-10", Left: 28'-1". Efforts to correct this condition were unsuccessful. Equally divided, this would result in a turning radius of 24'-11½", or in excess of the A.W. 99-H. It could be concluded that the A.W. 99-H had the shortest turning radius of the group.

The maximum road width of 8'-1" was 4'-7½" less than the minimum for any grader tested. This was conceded by observers to be a desirable feature and a decided advantage when operating on narrow roads.

The test showed conclusively that none of the tandem graders tested could make a minimum radius turn on a 12-foot road without backing.

(2) - Turn-Around. The results of the turn-around test are shown in Table XIV.

TABLE XIV

Turn-Around

Backups Required on	A.W. 99-H	Maximum Other	Minimum Other
35 Foot Road	2	4	2
30 Foot Road	3	8	5

The A.W. 99-H accomplished this test with the minimum backups required on any grader tested.

XIII. BRAKE TEST

The service brake on the A.W. 99-H was a single drum type, mounted directly on the drive shaft to front axle, and was activated by a hydraulic master cylinder. The parking brake was incorporated with service brake in the same drum, but was activated by a manually controlled linkage mechanism. Although the California State Vehicle Code for braking distances does not apply to Motor Patrol Graders, the stopping distance requirements were used as a check on the braking ability of motor graders.

The following table gives a comparison of the holding and stopping ability of service and parking brake of the A.W. 99-H as compared with the maximum and minimum values for other machines tested.

TABLE XV.

Brake Tests

	A.W. 99-H	Other Machines Tested	
		Maximum	Minimum
Serv. Brakes Uphill Hold	49%	49%	21%
Serv. " Downhill "	49%	49%	34%
Park. " Uphill "	49%	49%	21½%
Park. " Downhill "	49%	49%	14%
Stopping Dist. at 18 mph	15 ft.	38 ft.	19 ft.

California State Vehicle Code Stopping Distance at 18 mph - 30 ft.

The above table indicates that for braking ability on steep grades at slow speeds, the service and parking brakes on the A.W. 99-H were adequate. For quick stopping at high speeds, the service brakes were more than adequate. However, after careful analysis of the A.W. 99-H brake system, it was the opinion of observers that as a whole the system was inadequate for the braking requirements encountered in Forest Service Operations.

Objectionable features are explained as follows:

1. Service brakes confined to a single drum. Effective brake lining to drum area is questionable in relation to machine weight. As experienced and included later in this report, friction and heat caused the brake to be entirely ineffective in stopping this grader after a long downhill run. All other graders tested had two or four wheel service brakes.

2. Service and parking brakes included in single drum. With this combined feature, the element of safety had to be considered. It was reasonable to assume that any fault or failure which could occur to the service brake would also involve the parking brake, thus increasing the possibility of having no effective brakes on the machine. A separate parking brake was considered desirable and necessary. All other graders tested had an independent parking brake.

3. Service brakes on drive shaft. All braking effort was transmitted to wheels through the driving mechanism. Although this is an accepted braking method on vehicles and the mechanism may have been designed to adequately withstand the braking effort imposed, there was question as to ability to withstand the loading under the conditions to be found in Forest Road operations.

Although it was evident from the tests that the stopping and holding ability of the A.W. 99-H brakes was better than the normal requirements, it was the consensus of observers that they were inadequate for the reasons cited.

XIV. WALKING TEST

1. The highway walking test was divided into two sections. The first covered travel over asphalt paved highway with grades up to two percent. The second section covered travel over dirt highway with grades up to eight percent.

2. The truck trail walking test was divided into uphill and downhill sections. Grades varied from 14 percent uphill to 10 percent downhill.

Table XVI gives comparative speed data in miles per hour for each section of the highway and truck trail runs as well as overall mph for each distance.

TABLE XVI

Travel Speed (mph)

Route	Distance	A.W. 99-H	Other Graders Tested	
			Maximum	Minimum
Paved highway	4.2 Mi.	15.80	24.60	18.30
Dirt highway	1.9 "	12.35	17.54	14.07
Total highway	6.1 "	14.50	19.94	17.70
Uphill truck trail	1.35 "	6.11	6.56	4.49
Downhill truck trail	2.3 "	9.13	16.24	9.69
Total truck trail	3.65 "	7.70	9.98	8.27

In both the highway and truck trail travel speed tests, the A.W. 99-H was recorded as the slowest of all machines tested. It was during the latter test that the service and parking brakes failed to hold the grader to a desired speed, nor could the unit be braked to a stop. As noted in Table XVI the downhill test consisted of 2.3 miles of narrow winding road with one short radius curve and numerous curves of variable radius, the average grade was 9%.

The Forest Service operator did not realize the steepness of the down-grade and shifted to a higher gear than should have been used. Consequently, the brake was used excessively, became too hot resulting in a near miss to a serious accident. Stopping the grader was difficult during remainder of the test. Obviously the operator was at fault in misusing the brakes, but the fact that it could happen with any operator, emphasizes the need for a separate emergency brake.

XV. BREAKDOWNS

The A.W. 99-H did not fail during the tests because of breakdowns.

XVI. FINAL CHECK

On completion of the field tests, all machines were returned to the "flatland" area. All complaints recorded were given a final check. In addition, a thorough check of each grader was made by shop mechanics.

Only one minor item was detected in the final check of the A.W. 99-H. A small crack was found in a part of the circle lock device. Since the part was under no evident stress and the crack was in a weld, it was concluded to be a weld shrinkage break.

DISCUSSION OF RESULTS

Field Tests

I. SLIDE REMOVAL

One fact which became apparent during field tests was the lack of knowledge of various operators as to how much work a machine was capable of doing. In the slide removal test, several of the operators questioned the ability of any grader to perform the task assigned. As the tests progressed, the performance of machines improved as the operators gained more experience. Table XVII gives comparative times required for machines to climb over the test slide.

TABLE XVII

Slide Removal

	A.W. 99-H	Other Machines Tested	
		Maximum	Minimum
Time to Climb Slide	50 Min. 0 Sec.	41 Min. 0 Sec.	15 Min. 57 Sec.

The time required to climb the slide was reflected in a combination of operator and grader ability, plus the method used. For example, the time for one machine on a rerun was one fourth the original time. The reduced time factor was attributed to two causes: First, the operator gained experience by his original operation of a grader on a test with which he wasn't familiar. Second, in the interim, he had the opportunity to observe time saving techniques demonstrated by other operators performing the same test, thus enabling him to beneficially apply the experience and knowledge gained.

The true value of the slide test was not in determining the time required, method of attack, number of passes, etc., but in the appraisal of grader maneuverability, traction, blade stability, and operator fatigue.

Although the time for the A.W. 99-H was the highest recorded, due consideration was given to the fact that this machine was the first to attempt theslide test. Some graders reran the slide test to better their time; however, the A.W. 99-H performed satisfactorily and no rerun was thought necessary.

In this test, however, it was noted that complete loss of traction of either front wheel automatically voided all drive power to both front wheels, thus restricting power and tractive effort to the two rear wheels.

Although some unequal front wheel slippage was noted in other phases of the overall test, at no time was the A.W. 99-H considered lacking in tractive ability. Figure 13 shows slide used for this test.

Fig. 13. Test Slide A.W. 99-H

II. IN-CURVE

In figure 5 is depicted a typical condition often encountered in Forest road maintenance. Here the grader which was capable of turning a short radius curve, using the minimum road width, would have the advantage. Results of the test showed that the A.W. 99-H was far superior to the tandem graders. The average track width required for tandem graders was 19'-9", as against 9'-7½" for the A.W. 99-H. Data obtained from this test substantiated the conclusions of the "flatlands" turning radius runs.

III. GRADING OF DIPS

No difficulty was encountered with the A.W. 99-H in the grading of dips. Maneuverability of machine was adequate in all respects. It was anticipated by observers that the blade locking device might handicap operations in this phase of the test, but it was noted that the blade could be angled as desired by rear-wheel steering.

IV. DITCHING

This test was conducted in the same area and adjacent to test strips on which other units operated. This insured comparable operating conditions. The A.W. 99-H ranked second best in elapsed time. The table of ditching time, Table XVIII, shows the comparison between the A.W. 99-H and other machines in the test.

TABLE XVIII

Ditching

	A.W. 99-H	Other Machines Tested	
		Maximum	Minimum
Time to Construct Ditch	8 Hr. 58 Min.	11 Hr. 33 Min.	8 Hr. 20 Min.

It was recognized that this ditching test was most severe and beyond the normal operations encountered or anticipated. It was, in effect, an accelerated aging test to determine the ability of the graders.

In this difficult test the A.W. 99-H showed superiority in operating under heavy going without abuse to machinery. Maneuverability of the machine due to rear steering showed to advantage in removing the large embedded rocks. The power sideshift of the blade provided additional advantage for the A.W. 99-H in this work by side shifting the boulders from the work area. Since material was sidecast uphill, the tandem graders had difficulty in maintaining an "even keel" whereas the A.W. 99-H could steer both sets of wheels directly into the load thereby maintaining tractive effort in the line of thrust with minimum skidding down slope.

V. SCARIFYING

The work of scarifying the ditch surface was accomplished equally well by all graders. The A.W. 99-H completed this test without incident.

VI. BANK SLOPING

The A.W. 99-H accomplished the bank sloping test with ease and excelled in maneuverability, and control of both machine and blade. Since the rear wheels could be steered adjacent to the bank at all times, the job of banksloping of incurves was easily accomplished. Figure 14 and 15 shows bank sloping before and after operation.

Fig. 14. Area before Banksloping

Fig. 15. Banksloping Completed

VII. DRIFTING

TABLE XIX

Drifting

	A.W. 99-H	Other Machines Tested	
		Maximum	Minimum
Cu. yds./ Min. Moved	1.1	1.29	.97

The A.W. 99-H rated third best in this test. Although no particular difficulty was experienced, test observers critically compared the inability (referred to as an inability because not recommended by factory) of this unit to swing blade under load.

Other graders were noted to angle blade into bank material, fill blade, and without stopping machine, swing blade to straight across position and proceed to point of material dispersal.

In operation of the A.W. 99-H the blade was filled while angled, the grader was then stopped to unlock circle, blade was swung to straight across position and circle relocked. Material was then carried in the same manner as others. This procedure was comparatively more time consuming.

VIII. HORIZONTAL MOVEMENT OF WINDROW

In this test, results were reduced to cu. yds. ft. sidecast per minute. This factor is necessary for comparative purposes, since each machine moved a different quantity of dirt variable distances to the side, and in variable periods of time. Table XX gives the results.

TABLE XX

Windrow Cu. Yds.-Ft./Min.

A.W. 99-H	Grader			
	A	B	C	D
85.5	107.0	149.0	145.2	96.5

In production, the A.W. 99-H rated fifth. No difficulty was encountered during this test and the finished result was satisfactory. In analyzing the low production of the A.W. 99-H as compared to the other graders tested, it was decided by observers that this was the one test where the 76 horsepower engine was inadequate to operate with an out put comparable to that of more powerful graders.

IX. SHAPING OF BERMS

The work in this test was relatively light and all units were rated equally. No significant features or failures were evident.

X. HILL CLIMB

In this test all machines climbed the 49% grade in forward gear. In reverse, the tandem machines were able to back up to the section of the hill on which the slope varied from 39% to 41%. At this point failure was due to lack of traction. The four-wheel-drive A.W. 99-H was the only grader to climb the hill in reverse.

XI. UPHILL GRADING

Grades on sections selected for this test averaged about 15% and road bed material was chiefly decomposed granite. Table XXI gives the comparative overall time for the graders to complete grading on the 500 ft. test section of road.

TABLE XXI

Uphill Grading

	A.W. 99-H	Other Machines Tested	
		Maximum	Minimum
Time to do Uphill Grading (500')	3 Min. 35 Sec.	4 Min. 6 Sec.	2 Min. 50 Sec.

The A.W. 99-H completed this test satisfactorily in average time.

XII. ROAD GRADING

The three-pass 500 foot road maintenance test was preliminary to the two mile maintenance run. The satisfactory performance in this test assured observers of the ability of machine and operator to proceed with the longer test to follow.

XIII. ROAD MAINTENANCE

The two mile road maintenance test was the last of the field tests performed, and combined all of the operations normally required in road grading, with the exception of bank sloping. This being the composite of the previous tests, observers were able to recheck various phases of operation previously noted, as well as to appraise the ability of the machine in shifting from one operation to another with minimum loss of productive time.

The course selected for the A.W. 99-H test was 2 miles long, had 45 interceptor dips, and had grades up to 20 percent. The roadbed was chiefly decomposed granite. Three passes were made averaging 1.47 miles per hour, or a total time of 4 hours and 4 minutes for the test. Speed of other graders ranged from 1.52 to 1.9 miles per hour. A considerable portion of the variation in time for each grader could be directly attributed to operator differences in interpretation of the problem.

The Forest Service engineer, in his appraisal of this phase of the test, reported that performance of the A.W. 99-H was above the average in comparison to results obtained from other graders. The operator disregarded the time factor in favor of attaining quality results.

Appearance of the finished job was carefully observed in an attempt to detect instability of the machine due to absence of the tandem wheel feature. The smooth surface produced by the blade indicated that Fine grading could be accomplished by the A.W.

The advantage of four-wheel steering was very evident in this test since backing-up was unneccessary on sharp turns.

One feature of the A.W. which showed to advantage in the road maintenance test was its ability to place the berm on the extreme edge of the road bed on sharp outcurves where turn-outs were originally constructed. Side shift of the blade by the power ram, and rear wheel steering, made this type of work possible resulting in a more thorough maintenance job.

Many photographs were taken during the test. A few which show before and after conditions are included in Figures 16 to 19.

Fig. 16. Road Maintenance Section Before Test

Fig. 17. Road Maintenance Section After Test

Fig. 18. Road Maintenance - Dip Construction Before Test

Fig. 19. Road Maintenance - Dip Construction After Test

BULLDOZING TEST - FLATLAND AND FIELD

Due to the specialized nature of bulldozer attachments on graders, this portion of the test was treated independently of the basic grader test. Considerable interest in the possibilities of such an attachment was indicated by observers, and as a result, the Austin-Western Company and one other grader company voluntarily sent for and installed their respective dozer attachment for testing.

Fig. 20. A.W. Bulldozer

Comparative data for both dozer units taken in the Flatland Test was as follows:

	A.W. 99-H	Other Unit
Weight, blade assembly	1500 lbs.	880 lbs.
" attach. "	---	1480 lbs.
" total "	1500 lbs.	2360 lbs.
Blade length	9'0"	10'-1"
" height	3'-3½"	2'-7"
Pitch	Fixed	1°-8°+
No. cutting edges	1	2
Cutting edge size	8"Wx9'L	6"Wx5'L
Max. angle R	0° (Fixed)	33°
" " L	0°	33°
Type control	Hyd.	Mech.
Max. lift above ground	17"	17"
Max. lower below ground	6"	6"
Side shift range	0"	8" R and L

FIELD TEST OF SLIDE REMOVAL WITH DOZER ATTACHED

This particular operation was considered as the most logical application for a dozer attachment on a motor grader. It appeared reasonable that the machine would simulate a tractor with dozer in removing a slide by head-on approach. Figure 21 shows a picture of the slide area after removal by using bulldozer blade.

Fig. 21. Test Area after Dozer Operation

The first test of the machine was to remove sufficient slide material to allow the grader to pass over the obstruction. This was accomplished in 18 minutes as compared to 19 min. 10 sec. for the other unit.

A second test required that the slide be completely removed and the material spread on the road bed beyond. In this test, the A.W. 99-H required 2 hours 53 minutes as compared to 1 hour and 56 minutes for the other unit.

CONCLUSIONS

Conclusions formulated and expressed are the result of experience with and test of the machine submitted for trial.

FLATLAND TESTS

1. Weight distribution for the A.W. grader differed from any other grader tested due to four wheel drive.

2. Drive wheel weight horsepower ratio was highest of all graders tested because of four wheel drive.

3. Overall dimensions were less than those of any other grader tested.

4. Speed variations, as allowed by rear axle and transmission ratios, were adequate.

5. Engine performance is satisfactory.

6. Method and principle of starting is considered satisfactory.

7. Maneuverability of blade (with exception of circle lock) in all tested operating positions is entirely acceptable. It is the opinion of test observers that the A.W. 99-H has the most desirable features of blade maneuverability of all graders tested.

8. The side shift of the blade on the A.W. 99-H was considered the most desirable of the methods used on other graders tested.

9. Visibility from the cab was adequate for normal field operation.

10. Four wheel steer adequately handled operations requiring leaning front wheels on other type of graders.

11. Front axle ground clearance was less than that of any other grader tested. No difficulty because of lack of clearance was noted during the tests.

12. Daily maintenance requirements were considered reasonable.

13. Tires as furnished were the heaviest used during test. Wear was negligible.

14. Rims, as furnished, were satisfactory.

15. Fuel tank capacity was adequate for a full day's operation.

16. The time and effort required for cab removal and reinstallation was comparable to that of other graders.

17. Lights were satisfactory for forward travel, but only fair for blade illumination.

18. Controls were adequate and satisfactory with exception of circle locking device which is considered awkward to operate.

19. Comparatively, the action of hydraulic control levers was smoother and much less fatiguing than the mechanical type of controls as used on other graders.

20. Turning radius was the shortest of any other graders tested.

21. Service and foot brakes were not approved since they failed to perform satisfactorily on the truck trail road test.

22. Operational travel speeds were adequate for road maintenance. Highway speed was slowest of all units tested.

FIELD TESTS

1. While time required to accomplish the slide removal test was in excess of other graders, the A.W. was judged capable of performing this work satisfactorily.

2. The incurve test showed that the A.W. was the only grader which could operate on short radius curves where road width was less than 12 feet without backing.

3. Grading of dips was accomplished with ease.

4. In the ditching operation, the A.W. showed ability to operate under heavy loads without abuse to the machine and completed the job with comparative ease.

5. The A.W. had no difficulty in test scarifying operations.

6. In the bank sloping test the A.W. excelled. Four wheel steer and hydraulic control of the blade were the main contributing factors.

7. In the drifting test, the A.W. rated below average due to the necessity of stopping to release the circle lock.

8. The A.W. in the windrow test moved less material than average for other graders.

9. The A.W. was equal to all graders tested in climbing steep slopes in a forward direction and superior when in reverse.

10. The uphill grading test indicated that the A.W. could perform uphill to the required standard.

11. In the two mile maintenance test, the A.W. required more time than any other grader, but the quality of work was appraised as above average.

A P P E N D I X

RATING TABLE

As a check on the results of the motor grader test, a rating table was prepared to include several of the more common items generally considered when discussing patrol graders. The theory in the preparation of this table, if it can be so called, is based somewhat on the laws of random sampling.

Eight men - three engineers, one ranger, one mechanical draftsman-designer, two Depot Superintendents, and one Regional Office staff man - completed a rating table for the five graders, to include twenty-three items normally associated with equipment of this type. The items were listed only as headings with no detail to cover definition. Instructions for preparation requested that the rater draw his own conclusions as to the inference in the item, and rate accordingly. Rating was to be made by indicating the best as one, second best - two, etc., with machines of equal ability being rated by the same digit.

It was also recognized that all 23 of the rating items did not bear the same weights as to importance. Accordingly, each person preparing the questionnaire was requested to evaluate the relative importance of each and establish some weighting scale to cover.

A typical final form is shown with the items weighted, but without the ratings for the individual graders.

GRADER SCORING SHEET

	Weight Rating	A-C	Cat.	Rome	A-W	Adams
Blade Opr.	6					
Engine Starting	3					
Transmission Shift	5					
Opr. of Controls	6					
Breakdowns	4					
Availability of Parts	4					
Maint. Nec. to Opr.	1					
Walking Speeds	3					
Maneuverability of Machine	5					
Safety - Brakes	7					
Visibility	5					
Controls Shift	6					
Opr. Fatigue	5					
Opr. Training Necessary	1					
Dip Const. & Maint.	8					
Ditching	5					
Drifting	3					
Bank Sloping	2					
Scarifying	5					
Move Windrow	6					
Remove Slides	6					
Road Maint.	8					
Fine Grading	2					

The eight forms were converted to final rating in percent and are tabulated below:

RATING TABLE

Individual	Grader A	Grader B	Grader C	Grader D	A.W. 99-H
1	28.8	68.0	59.0	50.8	62.8
2	30.0	64.7	62.4	48.0	51.0
3	28.2	65.4	41.7	39.2	73.5
4	68.1	91.0	89.6	75.3	91.9
5	25.2	58.5	52.8	38.8	80.2
6	31.7	67.1	66.4	44.0	67.9
7	43.7	73.0	65.8	58.0	77.8
8	20.5	36.1	66.1	26.8	47.4
Average	34.5	65.5	63.0	47.6	69.1

It is significant that in all the ratings, Graders A and D held the positions of fourth and fifith respectively without transposition and by a substantial margin. Graders B and the A.W. 99-H changed from their averaged relative position three times, while Grader C changed only twice.

It is evident from the ratings that the concensus of the observers in mentioning the advantageous merits of each grader several times in the body of the report, can be substantiated, and is defined as follows:

A.W. 99-H	- Most often	- First
Grader B	- " "	- Second
Grader C	- " "	- Third
Grader D	- Definitely	- Fourth
Grader A	- " "	- Fifth

If further deduction from the table were permitted, and if the sample of eight men could be taken as a cross-section of the entire field, it could be concluded that the A.W. 99-H is the most desirable for overall Forest Service work, with Grader B and C as acceptable alternates. Graders D and A would, because of their relative low rating, be classed as undesirable.

Finally, it could be said that even though the A.W. 99-H is rated the highest, according to the table and comparison with the ultimate in graders for Forest Service work, it is only 69.1% effective.

AAA DETONATOR BRAKE TESTER

The electrically operated detonator brake tester, shown in photograph, Fig. A, is used to measure the effectiveness of equipment brakes. Mounted on the machine being tested, it is operated by two switches - the first controlled by an observer and the second mounted on the brake pedal.

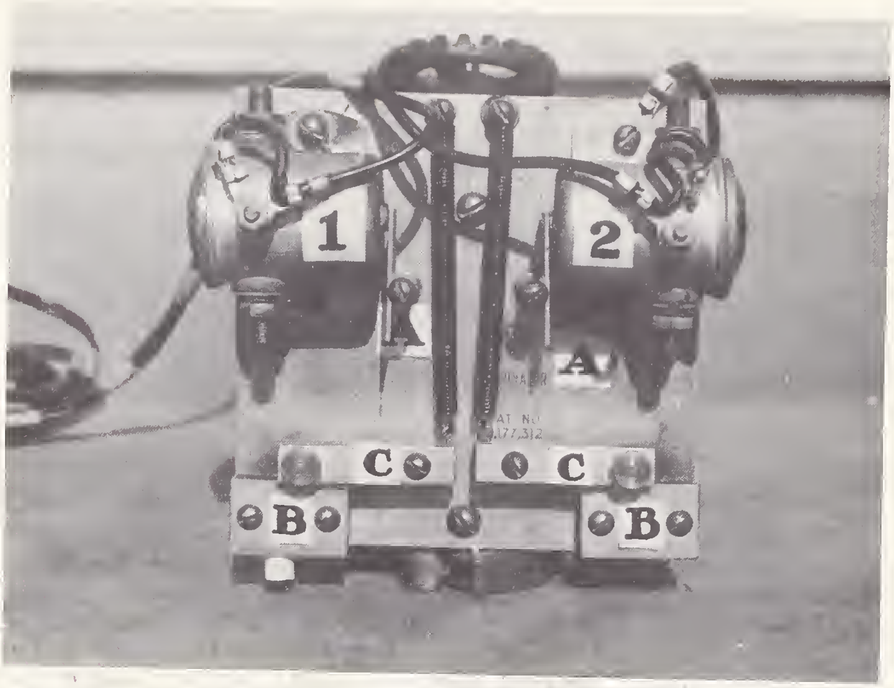


Fig. A. AAA Detonator Brake Tester

With the machine moving at the predetermined test speed, the observer operates the switch that releases solenoid 1 and allows its spring loaded hammer C to fire a blank cartridge in the block B. The force of the explosion expels chalk in the block and makes a mark on the pavement. On hearing the shot, the operator hits the brakes, causing the brake switch to release Solenoid 2, which fires a second piece of chalk to the pavement. When the machine comes to a complete stop a third chalk mark is made on the pavement directly under the detonator firing blocks.

The distance between the first and second shalk marks is measured and, since the speed of travel is known, can be converted into operator reaction time. The measurement between the second and third marks is the distance required to bring the vehicle to a stop at the given speed.

A complete description of the operation and use of this brake tester is available at the Arcadia Equipment Development Center, 701 N. Santa Anita Ave., Arcadia, California.