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NBSIR 75-953

A Procedure for Determining Bicycle Braking Performance

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Final Report

December 1975
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NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Acting Director*

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A PROCEDURE FOR DETERMINING BICYCLE BRAKING PERFORMANCE

Donald E. Marlowe

ABSTRACT

A procedure which could be used to determine bicycle braking performance for compliance with the Federal Bicycle Safety Regulation, Requirements for Bicycles, has been developed. The procedure includes tests for brake system integrity and stopping distance performance. Sample data collection sheets and calculations are given.

Key Words: Bicycles, braking, consumer safety, handbrakes, testing.

1. SCOPE

1.1 General

This procedure was used for the testing of bicycles in accordance with paragraph 1512.18(d)(2)(i) Loading Test, paragraph 1512.18(d)(2)(iii) Rocking Test, and paragraph 1512.18(d)(2)(v) Performance Test of the Federal Bicycle Safety Regulation, Requirements for Bicycles, Federal Register, July 16, 1974, and its amendments.

1.2 Test Samples

Bicycles which are proposed for sale on the retail market were tested for brake performance using the test procedure with the equipment outlined below or its equivalent.

1.3 Test Flow

The flow of procedures which were followed in the tests is shown in Figure 1.

2. APPLICABLE DOCUMENTS

The documents which are applicable to these tests are:

Requirements for Bicycles, Part 1512, Federal Register, Vol. 39, No. 137, July 16, 1974; as amended, Federal Register, Vol. 40, No. 220, November 13, 1975.

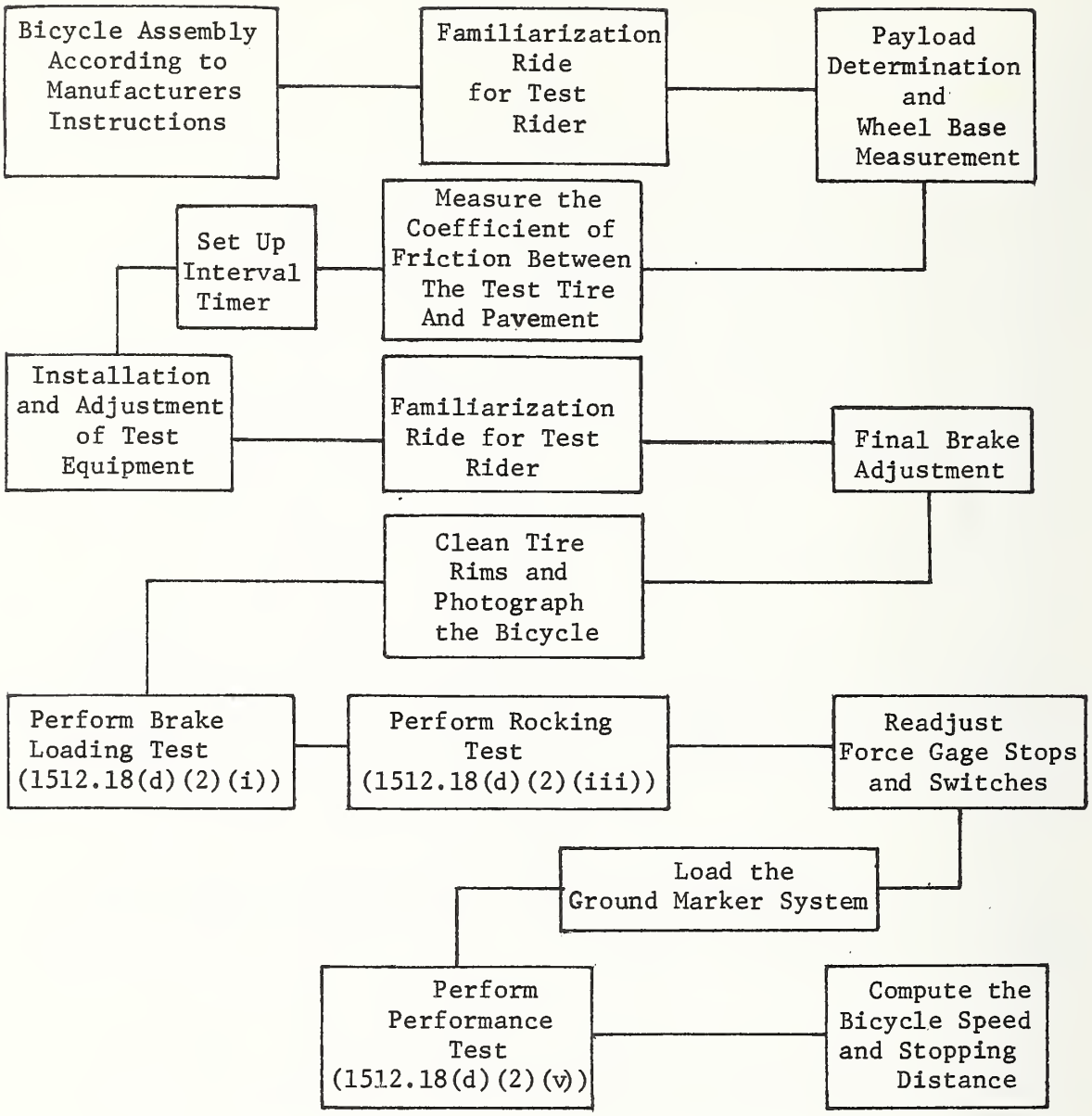

Fig. 1 Flow Diagram of Test Procedures

Mordfin, L., The CPSC Road Test of Bicycle Braking Performance - Kinetic and Error Analysis, NBSIR 75-786, October 1975.

Marlowe, D. E., The CPSC Road Test of Bicycle Braking Performance - Experimental Evaluation, NBSIR 75-755, August 1975.

3. TEST EQUIPMENT

Tests were performed using the test equipment listed in Table 1 or its equivalent.

4. PRECAUTIONS

4.1 Environment

(1) All testing was performed on a dry, clean, smooth paved surface free from protruding aggregate. The coefficient of friction between the tire and test surface was always less than 1.0 as determined on the bicycle being tested (see section 4.3). The pavement had a slope of less than one percent.

(2) The wind velocity during the tests did not exceed 11 km/hr (7 mph).

4.2 Rider Safety

(1) All riders were equipped with a riding helmet and clothing to limit the degree of injury should an accident occur during testing. Suitable clothing should include abrasion resistant pants, jacket and gloves similar to those used by professional motorcycle riders.

(2) The rider was encouraged to gain familiarity with the performance characteristics of the test bicycle. The familiarization took place with the bicycle equipped for testing. Several test runs, similar to the performance test run, but at lesser speeds, were made.

4.3 Equipment Check-out

(1) The coefficient of static friction between the bicycle and test surface was measured. A weight of 68.1 kg (150 lb) was placed on the bicycle seat. The weight distribution of the bicycle was determined by placing a platform scale or load cell weighing system under each wheel. The rear wheel of the bicycle was locked to prevent its rotation. A force gage was attached to the locked wheel near the tire-pavement interface. Steadily increasing forces were applied to the wheel in a direction parallel to the test surface until the wheel began to slide on the surface. The coefficient of friction between the tire and pavement is the ratio of the maximum tractive force parallel to the surface to the load distributed onto the rear wheel.

Table 1 - Test Equipment for Bicycle Braking Tests

Item No.	Description
1.	Tire inflation pressure gage, 7×10^5 N/m^2, (100 psi) capacity.
2.	Steel tape measure.
3.	Scales-91 kg (200 lb) capacity.
4.	68.1 kg (150 lb) mass (rider dummy)
5.	Force gage - 900 N (200 lbf) capacity.
6.	Rear wheel loading fixture.
7.	Rear wheel locking pin.
8.	Electronic timer.
9.	Tape switch, 2 m (6 ft) length.
10.	12 volt rechargeable battery, (2), with charger.
11.	Force gage assembly with marker system firing switches.
12.	Force gage - 450 N (100 lbf) capacity, (2).
13.	Ground marker gun with marker loads.
14.	Wiring for marker gun.
15.	Extension lever stops.
16.	Tape switch, 5 cm (2 in) length for actuating marker gun.
17.	Firing switch for coaster brakes.
18.	Riding helmet.
19.	Riding gloves.
20.	Riding coveralls.
21.	Alcohol and rag.
22.	Camera.
23.	Data sheet.

(2) Batteries for the ground marker system and velocity timer were fully charged at the start of testing.

(3) Bicycle tires were inflated to the pressure recommended by the tire manufacturer and molded into the tire sidewall.

5. PROCEDURE

The test procedures described in the following sections are not unique and were determined somewhat by the equipment available at the time the tests were conducted. These tests were designed to evaluate the structural integrity of the braking system (Loading Test and Rocking Test), to insure that the coefficient of static friction between the tire and test pavement is within acceptable limits, and to evaluate the dynamic stopping capability of the bicycle (Performance Test). The braking systems to be tested using these procedures include those actuated from primary hand brake levers, from auxiliary or extension hand lines, and from foot pedals.

5.1 Preliminary Checks and Measurements

STEP	DESCRIPTION
1.	Fully assemble the bicycle using the instructions provided by its manufacturer.
2.	Adjust all brake and shift linkages in accordance with the instructions.
3.	Inflate the tires to the maximum pressure recommended by their manufacturer.
4.	Ride the bicycle to insure that all adjustments are properly made.
5.	Measure the wheel base of the bicycle. This measurement is made from the center of the front axle to the center of the rear axle to the nearest 0.1 cm (0.05 in). Record the wheel base on the data sheet (Table 2).
6.	Weigh the test equipment. Record the weight (Table 2).
7.	Weigh the rider. Record the weight (Table 2).
8.	Affix a 68.1 kg (150 lb) mass to the bicycle seat.
9.	With the bicycle level and upright, measure the ground force at the rear wheel. Record the weight (Table 2).
10.	Position the bicycle on the test pavement in the vicinity of the expected stopping tests.

11. Attach the force gage to the rear wheel of the bicycle near the ground (Fig. 2).

12. Lock the rear wheel to prevent its rotation (Fig. 2). The front wheel must be free to rotate.

13. Using the force gage, apply steadily increasing forces to the wheel, parallel to the test pavement and in the plane of the wheel. Continue loading until the tire slides on the pavement. Record the maximum force (Table 2).

14. Compute the coefficient of friction for the particular tire-pavement combination as the ratio of the maximum applied force (item 13) to the weight on the rear wheel (item 9).

15. Verify that the above coefficient of friction is less than 1.0 (1512.18(d)(2)(v)(i)).

16. Remove the test mass from the bicycle.

17. Connect the external power plug to the electronic interval timer.

18. Connect the triggering tape switch to the battery (Fig. 3).

19. Connect the battery package to the timer.

20. Position the triggering tape switch across the test pavement.

5.2 Test Equipment Setup

5.2.1 Caliper Brake System

5.2.1(a) Primary Brake System

STEP	DESCRIPTION

1. Remove all handgrips, wrapping tape, end plugs, etc., from the handlebars.

2. Position the force gage assembly on the handlebars and fasten with the friction clamp (Fig. 4).

3. Attach the lever clamp to the brake lever so that the center of the clamp is 25 mm (1 in) from the lever end (Fig. 5).

4. Adjust the position of the brake lever on the handlebar such that the line of action of the force gage will be straight when the lever is fully depressed.(Fig. 6)

5. Using the force gage assembly, apply 445 N (100 lbf) to the hand brake lever.

Table 2 - Braking Test Data Sheet

a) Bicycle Manufacturer_____

Serial No._____

Model No._____

b) Test Data_____

c) Rider_____

d) Bicycle Information

Wheel Size_____ in

Max Gear Ratio_____

Brake Type_____

Brake Mfg._____

Frame Size_____ lbf

e) Test Information

Wheel Base_____ in

Equip. Weight_____ lbf

Rider Weight_____ lbf

f) Loading Test

Load on Force Gage_____ lbf

Lever Hit Bar_____

Pass-Fail

g) Rocking Test

Pass-Fail

i) Coefficient of Friction

Bicycle weight_____ lbf

Force applied to wheel_____ lbf

h) Performance Test

Run No.	Elapsed Time for Speed Measurement sec	Direction of Run	Stopping Distance from Rear Most Marker ft	Distance Between Markers: L-R Coordination ft	Distance Between Markers: Application of 40 lbf ft	Skidding

Fig. 2 Test setup for measurement of coefficient of friction

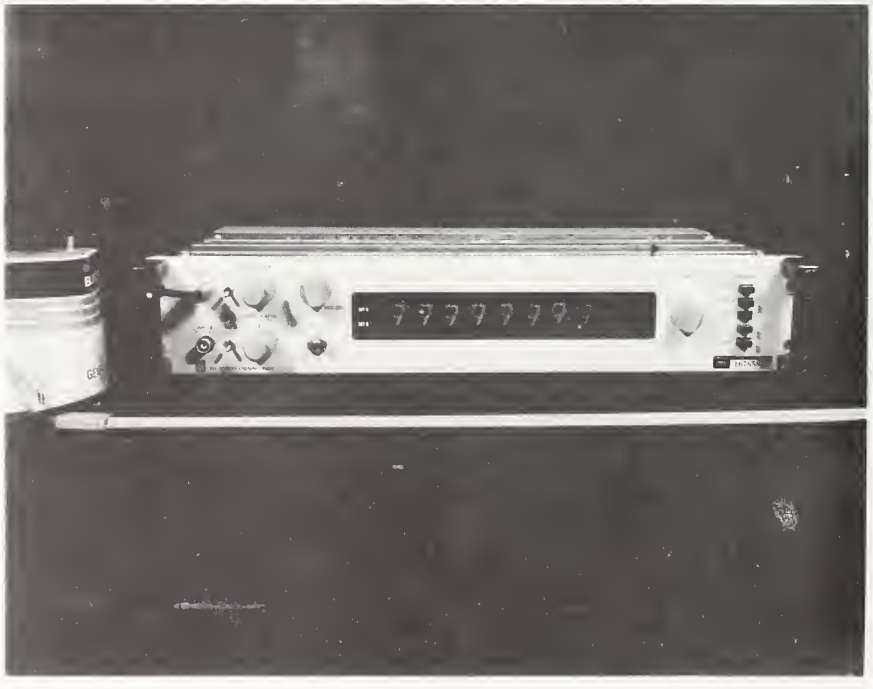

Fig. 3 Velocity timer setup

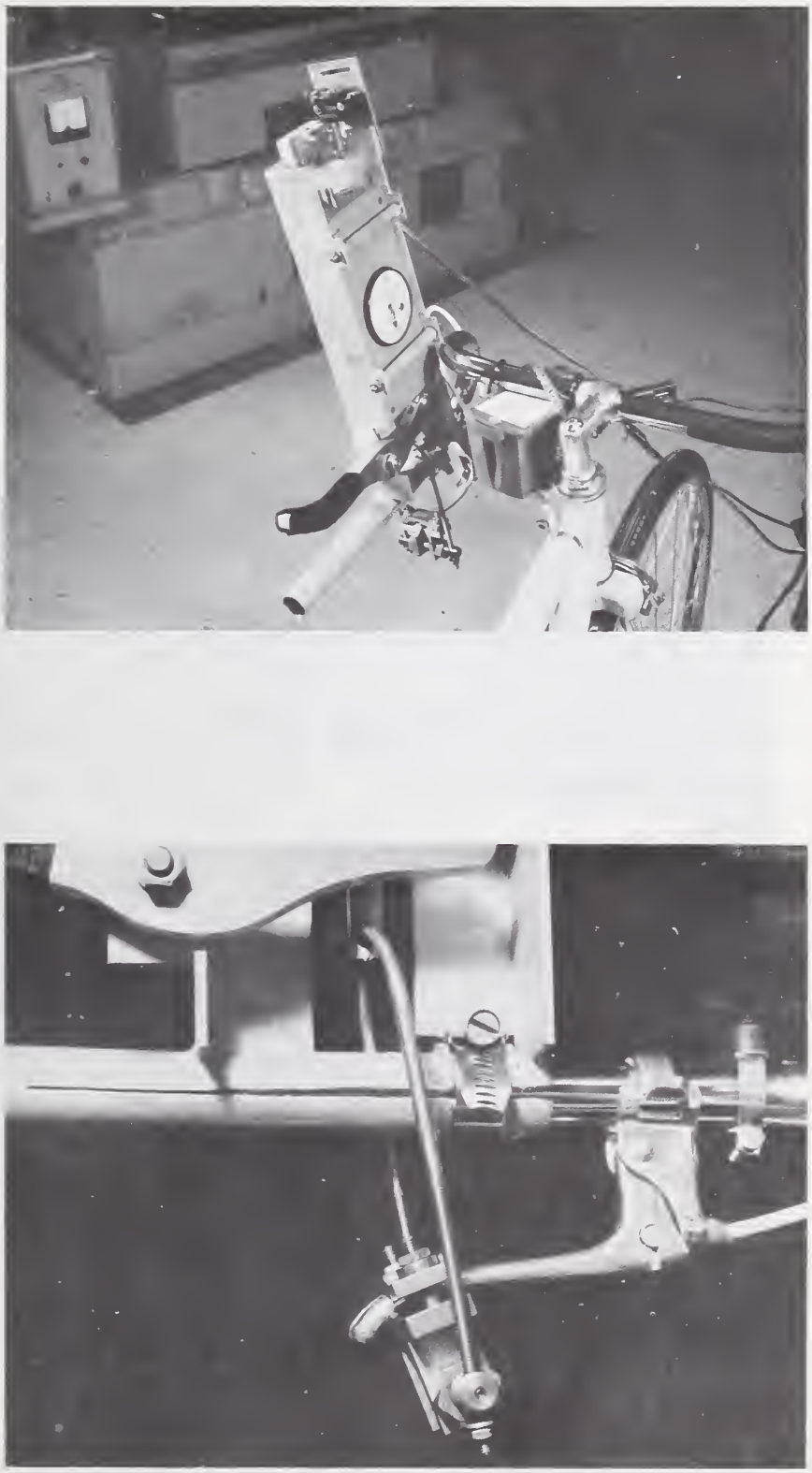

Fig. 5 Lever clamp of force gage prior to actuation

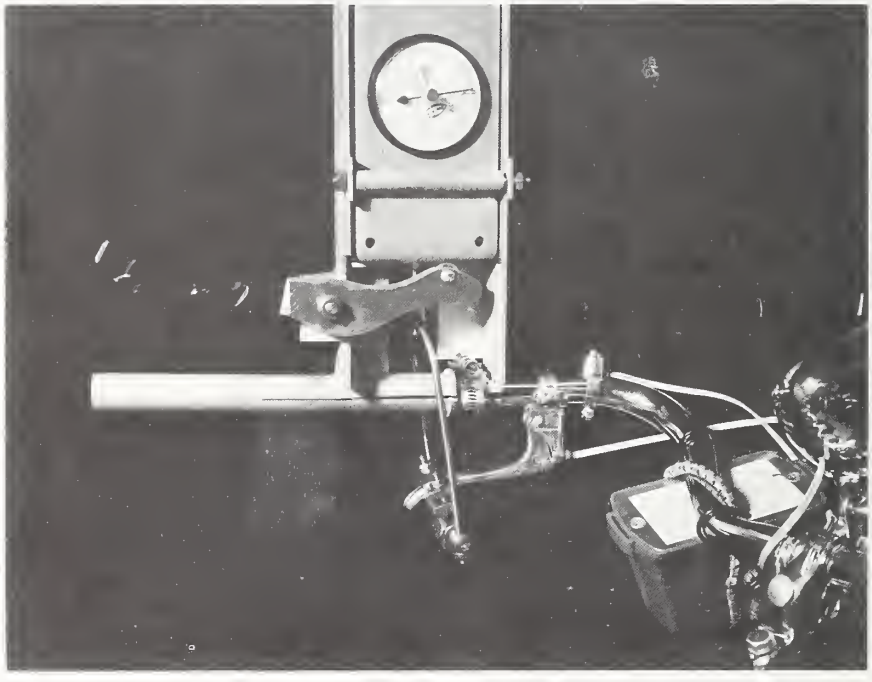

Fig. 6 Force shall be applied along the line of action of the force gage after actuation.

6. Adjust the stops (Fig. 7) on the force gage assembly to limit the applied force to a maximum of 445 N (100 lbf).

7. If the clamp bottoms against the handlebar at a load less than 445 N (100 lbf), readjust the position of the clamp (Fig. 8).

8. Remove the 445 N (100 lbf) load from the brake system.

9. Adjust the length of the force gage clamp linkage to insure that the brake system is fully unloaded and no braking forces are being applied to the braking system.

10. Install the ground marker gun on the front fork of the bicycle (Fig. 9).

11. Strap or tape the ground marker system battery to the bicycle in any convenient location (Fig. 4).

12. Connect the wiring to the battery, gun and firing switches on the force gage assembly (Fig. 10).

13. Connect the ground wire from the marker gun to the battery.

5.2.1(b) Extension Lever System

STEP	DESCRIPTION

1. Install the extension lever stops on the handlebar.

2. Adjust the position of these stops so that the extension lever travel beyond the top surface of the handlebar is prevented (Fig. 11).

3. Install the ground marker gun on the front part of the bicycle (Fig. 9).

4. Strap or tape the ground marker system battery to the bicycle in any convenient location (Figs. 4 & 11).

5. Install the firing switch on the extension level (Fig. 11).

6. Connect the battery to the switch and gun (Fig. 10).

7. Connect the ground wire from the gun to the battery.

5.2.2 Coaster Brake System

STEP	DESCRIPTION

1. Install the ground marker gun on the front fork of the bicycle (Fig. 9).

2. Strap or tape the ground marker system battery to the bicycle in any convenient location (Figs. 4 & 11).

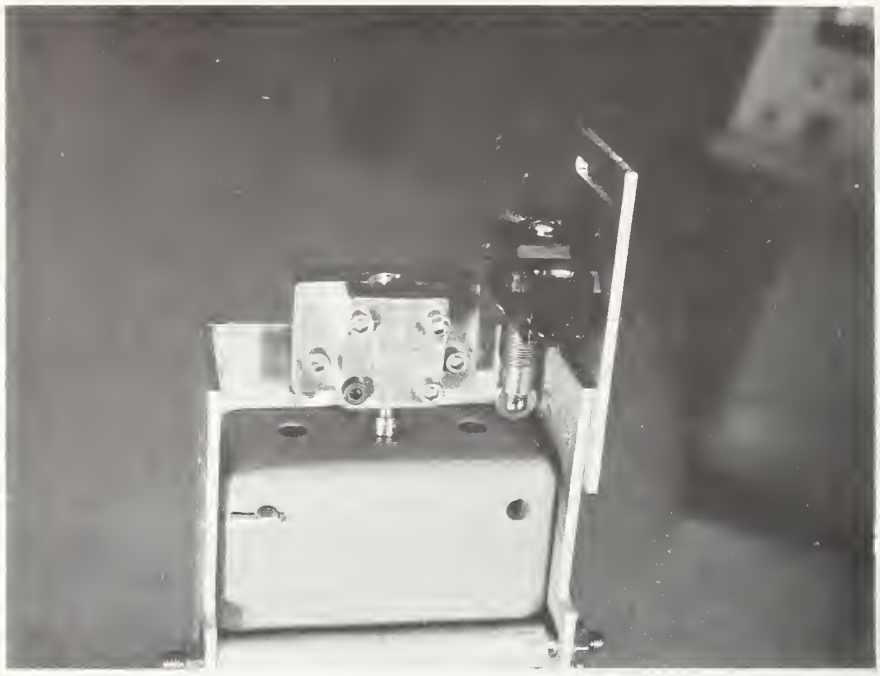

Fig. 7 Limit stops and switches on the force gage

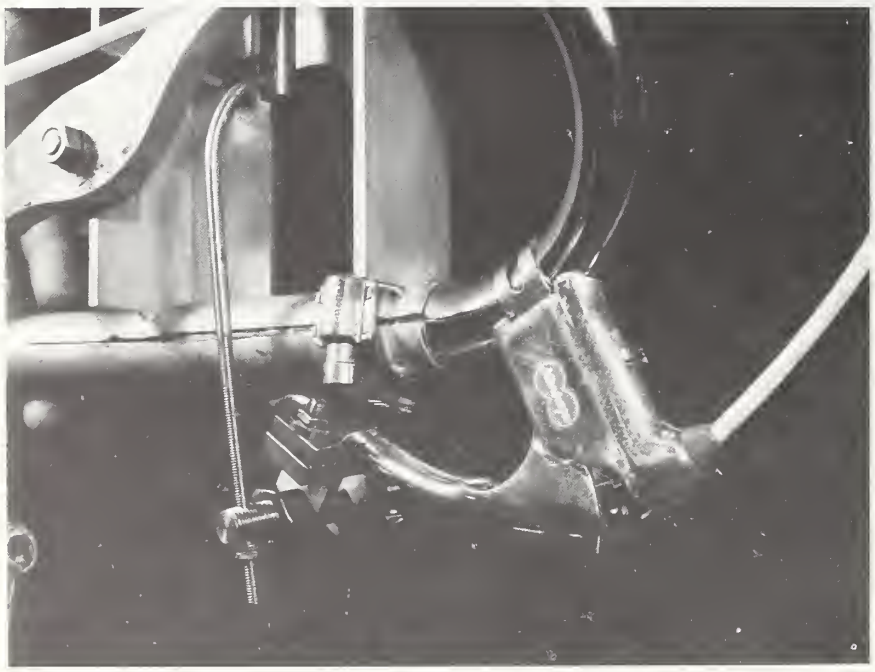

Fig. 8 Lever clamp adjusted to allow the lever to bottom against the handlebar

Fig. 9 Ground marker gun

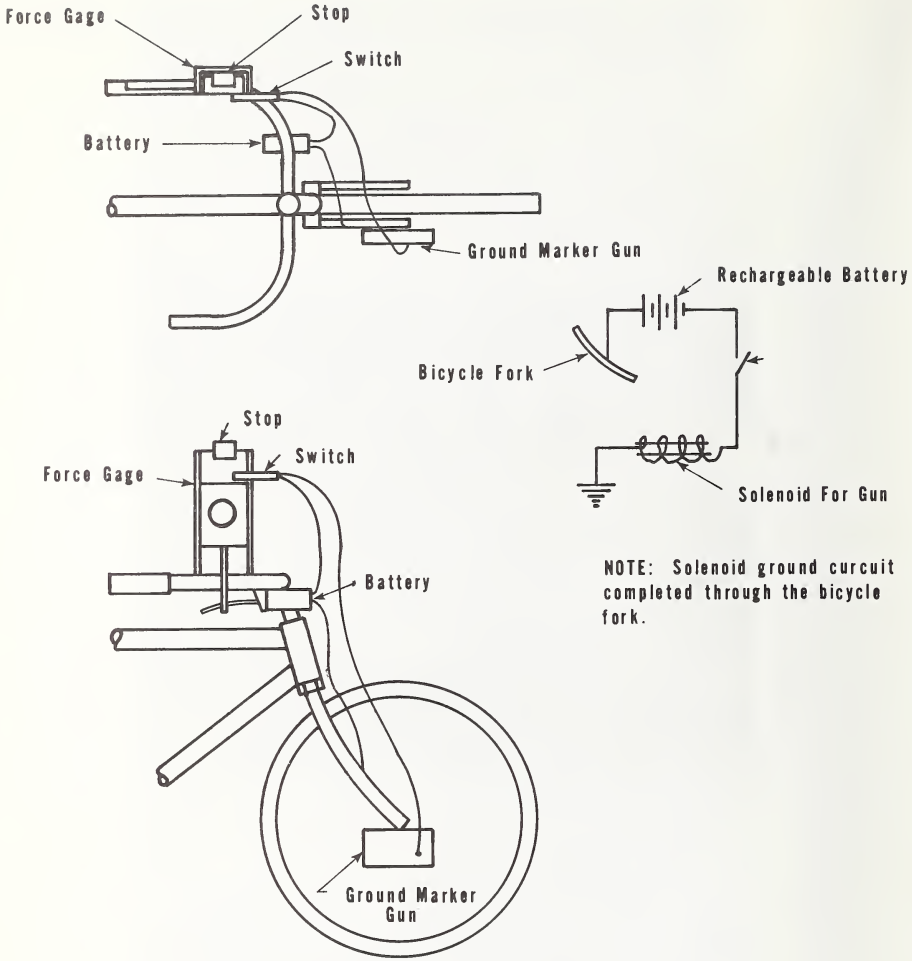

Fig. 10 Schematic of marker gun firing circuit

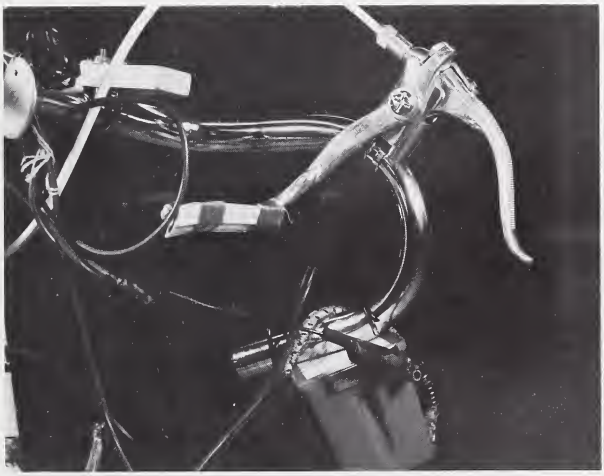

Fig. 11 Test setup for extension lever

3. Install the firing switch on the seat tube (Fig. 12) so that any rearward motion of the chain causes the switch to close.

4. Connect the battery through the switch to the gun.

5. Connect the ground wire from the battery to the gun.

5.2.3 Caliper-Coaster Brake Combinations

To conduct tests on these systems, use procedures discussed above in sections 5.2.1 and 5.2.2 of the procedure. Both systems must be tested simultaneously.

5.3 Final Checks and Adjustments

STEP DESCRIPTION

1. Check the rider's safety equipment. The rider shall wear a riding helmet and leather gloves plus a pair of durable coveralls or other riding attire.

2. Familiarize the rider with the behavior characteristics of the bicycle as it is equipped for the performance tests. This shall include several stops similar to those needed in the performance test but from lower speeds.

3. Adjust all brake system linkages and clearances in accordance with the manufacturer's instructions. This is the final adjustment which is permitted under the regulation (1512.18(d)(2)).

4. Wipe the tire rims of the bicycle using a clean cloth dampened with alcohol to remove any residue from earlier bicycle use.

5. Photograph the bicycle as it is set up for testing.

6. Turn on AC power to the interval timer.

5.4 Compliance Test Procedure

5.4.1 Loading Test

All bicycles equipped with hand brakes (primary and/or extension levers) are to be tested in accordance with the Hand Brake Loading Test (1512.18(d)(2)(i)) of the regulation using the procedure as follows:

STEP DESCRIPTION

1. Using the force gage loading apparatus, apply load to the hand brake lever to a maximum of 445 N (100 lbf) or until the hand brake bottoms against the handlebar, whichever occurs first. Release the load.

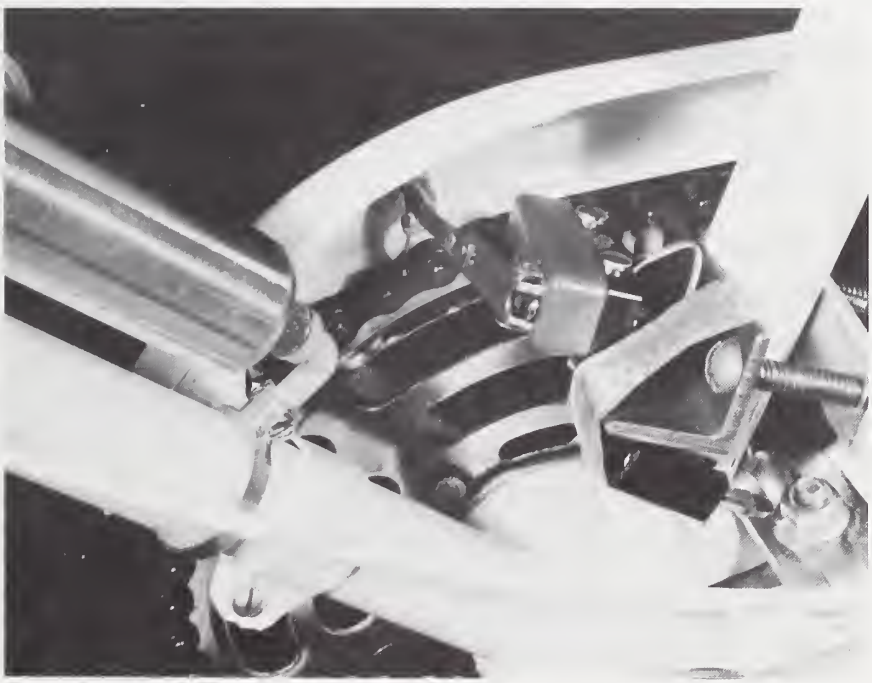

Fig. 12 Test setup for coaster brake

2. Repeat for a total of ten tests.

3. Repeat steps 1 and 2 for the extension lever system, if any.

4. Visually inspect the braking system after testing for fractures, failures, or misalinements which result from the test.

5. Record the results (Table 2).

5.4.2 Rocking Test

All bicycles equipped with hand brakes (primary and/or extension lever) are to be tested in accordance with the Rocking Test (1512.18(d)(2)(iii)) of the regulation using the procedure as follows:

STEP	DESCRIPTION
1	Affix a 68.1 kg (150 lb) mass to the bicycle seat.
2.	Position the bicycle on the test surface.
3.	Using the force gage loading apparatus, apply load to the hand brake lever to a maximum of 445 N (100 lbf) as in the loading test above (section 5.4.1, step 1).
4.	Drag the bicycle forward and rearward over the test surface for a total distance of 8 cm (3 in) in each direction.
5.	Repeat for a total of 6 tests.
6.	Visually inspect the braking system after testing for loosening of the brake pads, pad holder, or cable and hand-lever securing devices.
7.	Remove the 68.1 kg (150 lb) mass from the bicycle.
8.	Record the results (Table 2).

5.4.3 Performance Test

All bicycles are to be tested in accordance with the Performance Test (1512.18(d)(2)(v)) of the regulation using the procedure as follows:

STEP	DESCRIPTION
1.	On bicycles equipped with hand brakes adjust the stops on the force gage assembly (Fig. 7) or the extension lever (Fig. 11) to limit the applied force to a maximum of 180 N (40 lbf).
2.	Adjust the position of the firing switches (Fig. 7) so that the marker guns fire upon first actuation of the brake lever.

3. Load the ground marker guns with the paint cartridges.

4. Set the elapsed timer to zero.

5. Accelerate the bicycle to the specified test speed. Insure that the bicycle is traveling in a straight line at the test speed as it crosses the timing tape switch, and that the test rider is in the normal riding position. The test rider must remain in the normal riding position throughout the test.

6. Using the brake system(s) under test, stop the bicycle as rapidly as possible.

7. Note the presence of front wheel lockup, if any. A test run is invalid if front wheel lockup occurs.

8. Measure the stopping distance from the center of the rearmost ground marker along the original line of travel of the bicycle to the point opposite the center of the ground marker guns, disregarding changes in path which occur during the test. Record the distance (Table 2).

9. Record the elapsed time of the bicycle from the interval timer (Table 2).

10. Repeat steps 3 through 8 for a minimum of 4 test runs.

11. Compute the bicycle speed and corrected stopping distance using the equations and following the example shown in Fig. 13. Corrections for velocity at the initiation of braking may be made. The corrected braking distance shall be computed as follows:

$$S_c = \left(\frac{V_a}{V_m}\right)^2 S_m^5$$

where:

S_c = Corrected braking distance,

V_a = Specified test velocity,

V_m = Measured test velocity,

S_m = Measured braking distance.

The test run is invalid if at the commencement of the test, the measured test speed of the bicycle is not less than nor greater than the test speed required by this Part 1512 by 1.5 km/h (0.9 mph).

The stopping distances specified are based on a rider weight of at least 68.1 g (150 lb) and a maximum rider and weight combination of 91 kg (200 lb). Greater stopping distances are allowable for heavier riders and test equipment weights at the rate of 0.30 m per 4.5 kg (1.0 ft per 10 lb).

Bicycle Manufacturer
Serial No.

Bicycle Run No.	Speed Elapsed Time A	Wheel Base B	Measured Test Velocity C	Measured Stopping Distance D	Velocity Corrected Distance E	Bicycle Payload F	Load Corrected Distance G	Run Direction H	Average Distance I
	sec	ft	ft/sec	ft	ft	lb	ft		

Specified Test Velocity, V_s = Velocity required for test, FR 1512, January 28, 1976

Measured Test Velocity = $\frac{\text{Wheel Base}}{\text{Elapsed Time}} = V_m$

Stopping Distance, corrected for velocity = $\left(\frac{V_s}{V_m}\right)^2$ x Stopping Distance

Distance, corrected for load = Distance + 0.30 m for every 4.5 kg over 68.1 kg.
= Distance + 1 ft for every 10-lb over 150-lb.

Average Distance = Arithmetic Average of the Load Correct Stopping Distance (col. G) computed for all tests in which valid Stopping Runs were made.

Figure 13. Bicycle Performance Test Sample Calculation

5.4.4 Rider Coordination

On bicycles equipped with hand brake systems, it may be desirable to measure the actuation time of the braking system, i.e., the time from first actuation of the brake to the time the applied lever force equals 178 N (40 lbf). Similarly, it may be desirable to measure the rider coordination in actuating the brake levers, or for bicycles equipped with a single hand brake and coaster brakes, the time difference between actuation of these two systems. In these cases, the second chamber of the ground marker gun can be wired to the battery (see Fig. 10), and the firing switch adjusted to measure the desired parameter. A second ground marker gun can be mounted on the bicycle to permit various measurements to be made during a single test. For these measurements, assume a constant bicycle speed between the ground marks and calculate the resulting elapsed time. Record the distance between ground marks in Table 2.

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