Laboratory testing of slotted composition brake shoes = Expériences en laboratoire de sabots de freins fibrés à rainures

Allard, F. C.

Publisher's version / Version de l'éditeur:
https://doi.org/10.4224/23000770
Technical report (Low Temperature Laboratory (Canada)), 1984-08

D.E. MORRIS

Technical Report

Rapport technique

1984/08

TR-LT-001
NRC NO. 23707

LABORATORY TESTING OF SLOTTED COMPOSITION BRAKE SHOES

F.C. Allard

Division of
Mechanical Engineering

Division de
génie mécanique

National Research
Council Canada

Conseil national
de recherches Canada

Canada

UNLIMITED
UNCLASSIFIED

ILLIMITÉ
NON CLASSIFIÉ

LABORATORY TESTING OF SLOTTED COMPOSITION BRAKE SHOES

EXPÉRIENCES EN LABORATOIRE DE SABOTS DE FREINS FIBRÉS À RAINURES

F. C. Allard

Technical Report

Rapport technique

1984/08

TR-LT-001
NRC NO. 23707

T. R. Ringer, Head/Chef
Low Temperature Laboratory/
Laboratoire des basses températures

E. H. Dudgeon
Director/
Directeur

ABSTRACT

Four composition brake shoes were tested on a dynamometer to establish the effects of machined slots on brake shoe performance. Friction coefficients were determined for two wheel speeds and two brake load settings, under dry and wet weather conditions. Results showed no significant difference in performance between the slotted and unslotted brake shoes. Dry test results showed a reduction in friction coefficients with increased load and speed. The wet test results demonstrated that all brake shoes experienced hydroplaning, although unexpected erratic behaviour was exhibited by the diagonally slotted brake shoe at high speed conditions, yielding a slight increase in friction coefficient.

The validity of the laboratory testing procedure was also examined and proved adequate for comparative studies, although it may not have accurately reproduced actual wet field conditions.

RÉSUMÉ

Des essais ont été faits au dynamomètre utilisant quatre sabots de freins fibrés pour évaluer l'effet de rainures. Des coefficients de friction furent établis en se basant sur deux vitesses et deux charges différentes, sous conditions sèches et mouillées. Les résultats n'ont indiqué aucune différence appréciable de performance entre sabots à rainures et sans rainures. Les tests à sec ont démontré une réduction du coefficient de friction à vitesse accélérée et sous charge augmentée. Les résultats des tests sous conditions mouillées ont indiqué de l'hydroplanage pour tous les sabots de freins, mais il y a eut performance erratique pour les freins à rainures diagonales à haute vitesse, donnant une légère augmentation du coefficient de friction.

La validité des expériences en laboratoire a été examinée et fut considérée satisfaisante pour des études comparatives, quoique les tests ne représentaient peut-être pas parfaitement la situation sous conditions de pluie.

CONTENTS

ILLUSTRATIONS

CONTENTS (cont'd)

ILLUSTRATIONS (cont'd)

TABLES

APPENDIX

LABORATORY TESTING OF SLOTTED COMPOSITION BRAKE SHOES

1.0 INTRODUCTION

The National Research Council of Canada has been involved with a study of the effects of adverse weather conditions on the performance of composition brake shoes for trains. Tests have been performed, both in the field and in the laboratory, to determine the effects of water and snow on braking capabilities. Previous tests have concerned themselves mainly with analysis and comparison of AAR (Association of American Railroads) standard brake shoes supplied to the NRCC by various brake shoe manufacturers. After some discussion, it was felt that an investigation of the effects of slots in brake shoes on braking performance was warranted.

The problem which has been encountered with composition brake shoes is their inability to maintain sufficient braking under wet conditions due to a phenomenon known as hydroplaning. In an effort to improve braking under wet conditions, a set of composition brake shoes was machined with various types of slots and was tested in the Climatic Engineering Facility of the NRCC under simulated weather conditions. The objective of the testing was to determine whether the slotted brake shoes would perform better than an unmodified reference brake shoe under wet conditions.

The first phase of laboratory performance tests [Ref. 1] had been carried out on a new dynamometer test fixture mounted in a climatic chamber. The same basic fixture was employed for testing, again using a cylindrical wheel surface as opposed to a regular conical wheel surface. Both dry friction tests and wet fricton tests were conducted in the laboratory. Much emphasis was placed on careful and lengthy preparation of brake shoes prior to testing in order to obtain a contact area between brake shoe and wheel surface of at least 80 percent. Wheel and brake shoe temperatures were also carefully regulated for each test, as previous experience had shown that accurate test data was difficult to obtain on composition brake shoes [Ref. 1].

2.0 TEST FIXTURE

The Low Temperature Laboratory of the NRCC had previously held brake shoe performance tests at its Montreal Road facility. In April of 1984, the dynamometer test fixture was moved to the new Climatic Engineering Facility located near the Ottawa International Airport. This new facility was larger and could better provide a wide range of climatic conditions. The existing, specially machined cylindrical freight car wheel and axle set was to be used on the dynamometer. Some modifications to the mounting frame were necessary in order to install it at the new site.

A 600-volt, 3-phase AC source, with suitable transformer, was rectified to supply power to the 150 horsepower DC motor through a variable speed controller. An encased multi-vee belt was used as the drive between motor and axle. A steel pedestal was attached to the frame alongide the cylindrical wheel. From this pedestal, a brake shoe carrier assembly was suspended. A transport truck air brake cylinder was mounted on a support bracket along the horizontal centreline of the test wheel and attached to the carrier assembly to provide an air-operated normal brake load. In order to measure loads on the brake shoes during tests, a suitable tension load cell was incorporated between the brake shoe carrier and the pedestal to measure tangential force, and a compression load cell was fastened between the air cylinder actuator and the brake shoe carrier to measure normal force. Figure 7 shows the dynamometer test fixture. In the right foreground the protective cover for the multi-vee belt can be seen, while on the left the brake loading cylinder, the cylindrical wheel, and the cooling fan are shown. The brake shoe carrier assembly and load cells are shown in more detail in Figure 8.

A computer-based data acquisition system was utilized to collect test data, as seen in Figure 11. The computer program allowed for a copy of data to be produced for each test, along with a graphical representation of the data. In conjunction with the adjustable brake shoe carrier assembly, the computer program allowed adjustments to be made to compensate for variations in brake shoe size and weight. The computer program incorporated offsets for brake shoe load and for retarding force on the brake shoe, so that at zero wheel speed and no-load conditions the load cells would indicate no load. The adjustments in the linkages of the brake shoe carrier assembly ensured that when the brake shoe was engaged, the tension load cell centreline was tangent to the wheel surface in the vertical plane and that the compression load cell operated in a horizontal plane through the centreline of the test wheel.

3.0 BRAKE SHOE PREPARATION

A set of four composition brake shoes was tested in the Climatic Engineering Facility. Three of the shoes were machined prior to testing with 12.7 mm (1/2") deep by 3.2 mm (1/8") wide slots oriented in different directions. Shoe C-9, as seen in Figure 3, had six slots cut at 90° to the direction of wheel rotation, referred to as "transverse" slots; shoe C-11, as seen in Figure 4, had two slots cut along the drection of wheel rotation, referred to as "longitudinal" slots; shoe C-12, as shown in Figure 5, had six slots cut at a 30° angle to the direction of wheel rotation, referred to as "diagonal" slots; the final shoe, C-13, as seen in Figure 6, was unslotted and was to be used as a reference for comparison.

Before wear-in of the brake shoes on the dynamometer, the cylindrical test wheel was inspected. Surface roughness measurements [Table 4(A)], as well as a visual inspection, indicated that surface dressing was required. This was done using a specially designed hardwood dressing block, shown in Figure 10, and different grades of abrasive paper. A significant improvement was noted [Table 4(B)], after considerable effort.

Initial wear-in of the composition brake shoes was carried out on a special grinding fixture to reduce the period of time needed to obtain 80 percent contact fit between wheel and brake shoe. This fixture enabled rapid shaping of the shoe surface to the correct wheel radius. Yet, because of surface variations in the wheel, the wear-in required much hand filing and fitting, and proved to be a lengthy process. During wear-in, a large amount of heat energy was produced and the wheel and brake shoe temperatures increased rapidly. To prevent thermal damage to the brake shoes, it was necessary to keep brake applications short and to use forced air cooling between applications. Thus, wear-in often took several days for each shoe.

After wearing-in the brake shoes, copper-constantan thermocouples were installed in the composition material. Two thermocouples were placed, one at each end of the shoe, at a depth of 9.5 mm (3/8") below the contact surface, along the longitudinal centreline of the brake shoe. Figures 3 to 6 demonstrate thermocouples in place in the brake shoes.

4.0 TEST PROCEDURE

For all of the brake shoe performance tests, each of the four shoes was tested at speeds of 50 km/h (30 mph) and 80 km/h (50 mph) and at two load conditions for each speed. A maximum load of 8900 Newtons (2000 lbs) could be sustained by the motor drive and was chosen for the high setting. A load of 5800 Newtons (1300 lbs) was chosen for the low setting. As well, the chamber temperature was maintained at +15°C (59°F) and the wheel temperature lowered to 20°C (68°F) or lower at the beginning of every test. This was done to help eliminate anomalies in brake performance by maintaining a constant initial temperature for all tests. To speed up cooling between tests, a large wind fan was placed by the wheel and activated as required.

4.1 Dry Friction Tests

During the dry friction tests as many as eight test runs were conducted at each of the four test conditions to ensure that shoe-wheel contact had stabilized. From this group of test runs, a sequence of three consecutive runs was selected and used as tabulated data. Each test run lasted for roughly five minutes, with actual brake application lasting only 36 seconds. The short period of brake application was necessary to avoid thermal damage to the brake shoe, often experiencing temperatures over 80°C (176°F). Even so, at high speed and high pressure conditions, the heat energy produced from one short brake application required forced air cooling for nearly one hour.

To proceed with a test, the pressure valve to the air brake load cylinder was set to provide the required load condition;

the dynamometer was energized and necessary wheel speed obtained. The brake was then activated for a 36-second period during which time the load cell and thermocouple outputs were recorded at regular intervals by the data acquisition/control unit. The coefficient of friction for each run was determined from the values of normal and tangential forces recorded at the 24-second mark of each test run.

4.2 Wet Friction Tests

During the wet friction tests, a minimum of six test runs were conducted at each test setting to ensure that conditions had stabilized. From these, a sequence of three consecutive test runs was selected and used as tabulated data. From previous experience, it was decided that for wet tests a spray method based on icing cloud simulation would be utilized. The LTR-LT-143 report [Ref. 1] estimated a water concentration for wet testing to be adequate at roughly 2 g/m^3, the maximum liquid water content of a cumulus cloud [Ref. 2]. At a maximum speed of 80 km/h (50 mph) for a 6-inch wide, 36-inch diameter wheel, the swept volume would result in 375 ml/min. of water spray for this water concentration. To allow a safe margin for hydroplaning, it was decided that all wet tests would take place with a spray of 400 ml/min., regardless of speed. Two water atomizing nozzles were installed below the test wheel at the six o'clock position, approximately 13 cm (5 in.) from the surface of the wheel, to supply the required spray for the wet tests. A detailed view of these nozzles can be seen in Figure 9. This spray position allowed excessive amounts of water to be drained by gravity or to be removed by centrifugal force before making contact with the brake shoe surface, located 270 degrees from the atomizing nozzles.

The test procedure for the wet tests was similar to that for the dry tests, except that each test run lasted four minutes with steady brake application throughout. Water and air valves were adjusted to produce a total water flow of 400 ml/min. The coefficient of friction was determined from values of normal and tangential forces recorded at the 120-second mark of each test.

5.0 DISCUSSION OF RESULTS

All of the dry and wet friction tests conducted on the composition brake shoes are listed in Table 1, which provides data on brake shoe tested, type of test, speed range during the test, load setting, and, for wet tests, water flow rate supplied. Test results obtained were generally in agreement with results for unmodified brake shoes tested in Phase 1 of Laboratory Performance Tests [Ref. 1], although difficulties were encountered during brake shoe testing. Even after attaining 80 percent contact between shoe and wheel surface, repeatability of results was poor, especially if testing took place over more than one day. Often, it was necessary to carefully clean the shoe by hand in order to achieve results consistent with those of the previous day. As well, several hours of shoe preparation were needed even after requirements for 80 percent contact area had been met, in order to obtain a hard and smooth glazed surface on the brake shoe. In her thesis, "The Aquaplaning of Railway Brakes" [Ref. 3], K. P. Baglin indicates that thermally induced bending of brake shoes during braking makes it impossible to achieve identically repeated contact conditions. This, along with changes in climate in the test chamber, may offer some explanation for discrepancies observed during the test period.

5.1 Dry Friction Tests

Table 2 summarizes the results of the dry friction tests for the four brake shoes tested. All of the shoes displayed similar values for dry friction coefficients, the slotted brake shoes not differing significantly from the unslotted reference brake shoe. However, at the high brake shoe load condition, shoe C-9, with horizontal slots, did not behave as expected; it displayed an increased coefficient of friction at higher speed. All other shoes showed a reduction in coefficient of friction as a function of increased speed and load. By examining Figure 1, a comparison of friction coefficients shows that shoe C-12 had consistently higher values. Neither the behaviour of shoe C-9 nor that of shoe C-12 were regarded as significant because the changes were so slight.

5.2 Wet Friction Tests

The results of the wet friction tests are summarized in Table 3. All of the brake shoes tested experienced hydroplaning at the low speed conditions of 50 km/h (30 mph), with a spray of 400 ml/min. of water. At the high speed condition of 80 km/h (50 mph), brake shoe C-12, with diagonal slots, did not exhibit full hydroplaning, whereas the other three shoes did. At this speed, shoe C-12 behaved erratically, alternating between moments of hydroplaning and moments of high friction, approaching dry braking conditions. As well, during brake application, the shoe vibrated from side to side at right angles to the direction of wheel rotation. This unexpected behaviour was not a function of applied brake load, but apparently only occurred at high wheel speed. Figure 2 illustrates the results obtained for the wet tests. A question remains as to the effect of increased centrifugal force on the thickness of the hydroplaning film. It may be speculated that an angular redirection of the water film on the cylindrical wheel through the diagonal slots on the brake shoe may have caused a partial deterioration of the hydroplaning film. Irregular periods of increased braking resulted and produced the observed vibrations. Note that this is only a hypothesis and remains to be proven.

6.0 CONCLUSIONS AND RECOMMENDATIONS

Performance tests on the composition brake shoes have demonstrated that the slotted brake shoes would not perform better than the unmodified brake shoes under wet conditions. Values obtained for friction coefficients indicated no significant difference between slotted and unslotted shoes for both wet and dry tests. However, shoe C-12 demonstrated a slight improvement in braking performance in two instances, but the shoe behaved erratically and was accompanied by vibration. This, along with other factors such as increased cost of production and higher risk of shoe fracture, would make slotted brake shoes unsuitable for normal railway use.

The dynamometer test fixture successfully provided a means of comparative testing for the brake shoes under controlled climatic conditions. The validity of the testing procedure was somewhat hampered by poor repeatability of test results. To offset this problem in future tests, a larger number of similar brake shoes should be supplied and tested. A comparison of results for two or three of the same types of shoes would provide a check on the proper functioning of the dynamometer and yield more meaningful results. The wet tests, although not necessarily realistic in comparison with actual field conditions, still enabled a comparison to be made between brake shoes and thus satisfy the objective of the tests.

7.0 REFERENCES

1. Ringer, T.R. "Railway Composition Brake Shoes - Laboratory Performance Tests - Phase I" National Research Council of Canada, Report LTR-LT-143, September 1983.

2. Brown, E.N. "A Flowmeter to Measure Cloud Liquid Content". Atmospheric Technology, No. 1, 1973, pp. 49-51.

3. Baglin, K. P. "The Aquaplaning of Railway Brakes". Whitworth Fellowship Award, June 1981, pp.70-72.

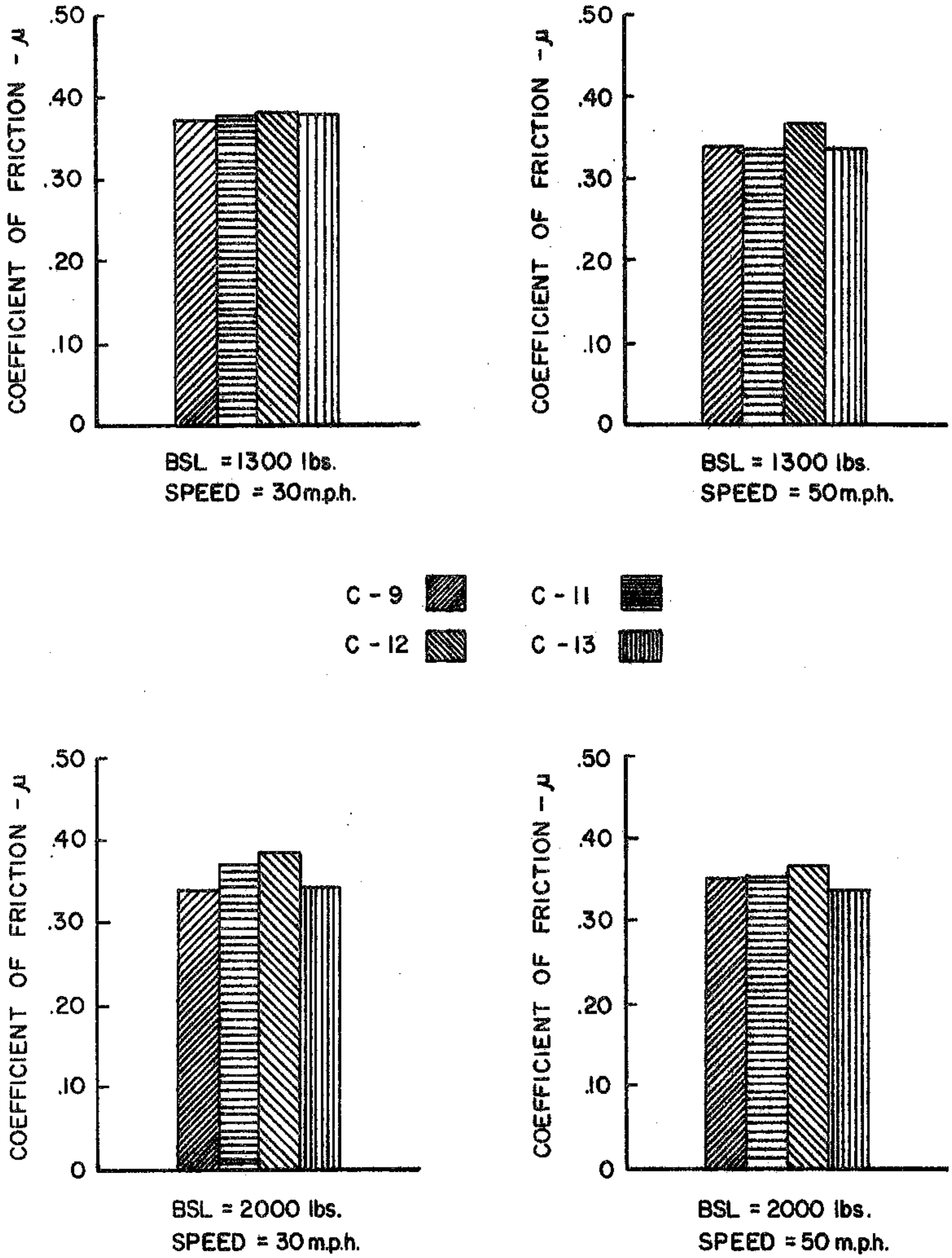

FIG. I COMPARISON OF FRICTION COEFFICIENTS - DRY TESTS

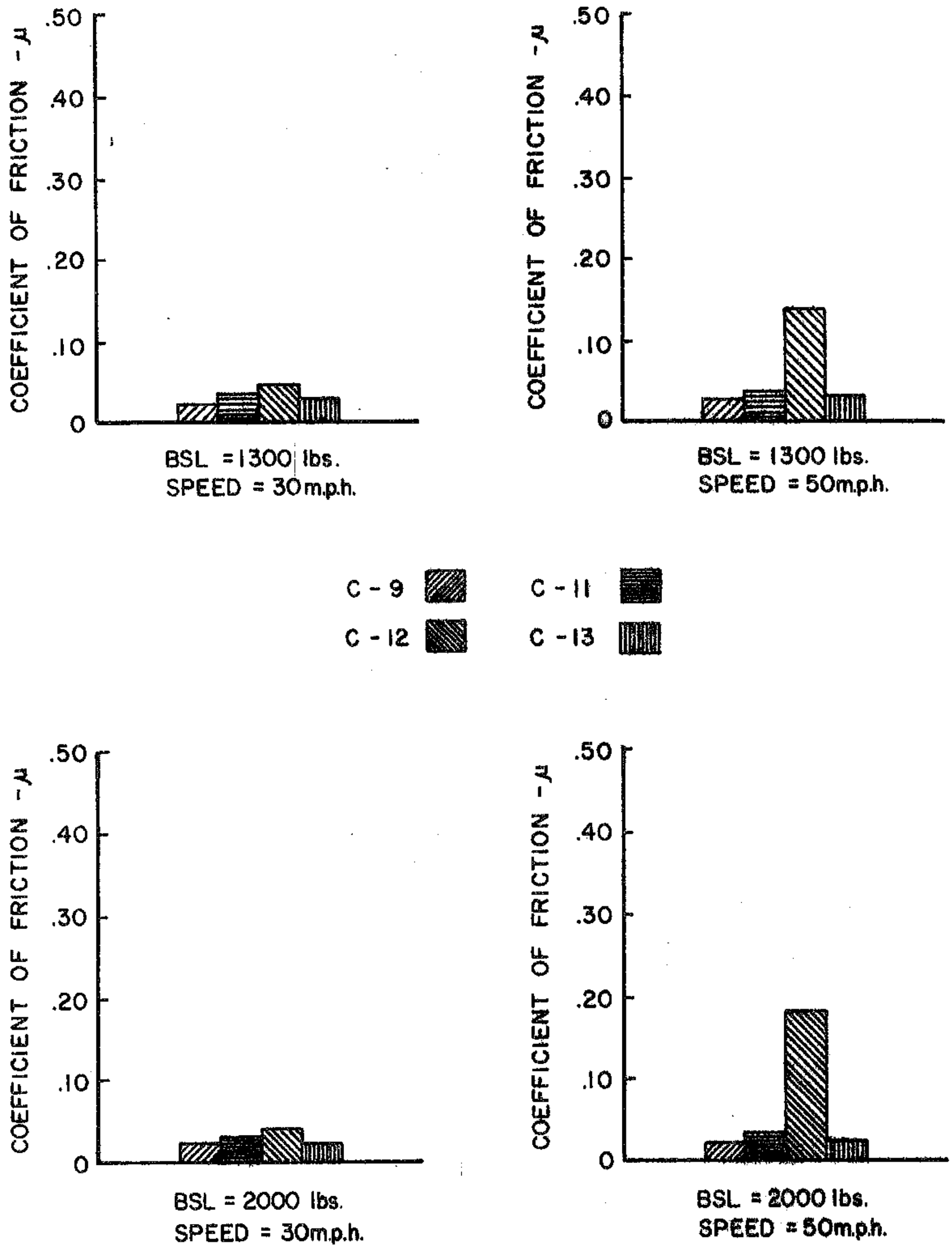

FIG. 2 COMPARISON OF FRICTION COEFFICIENTS — WET TESTS

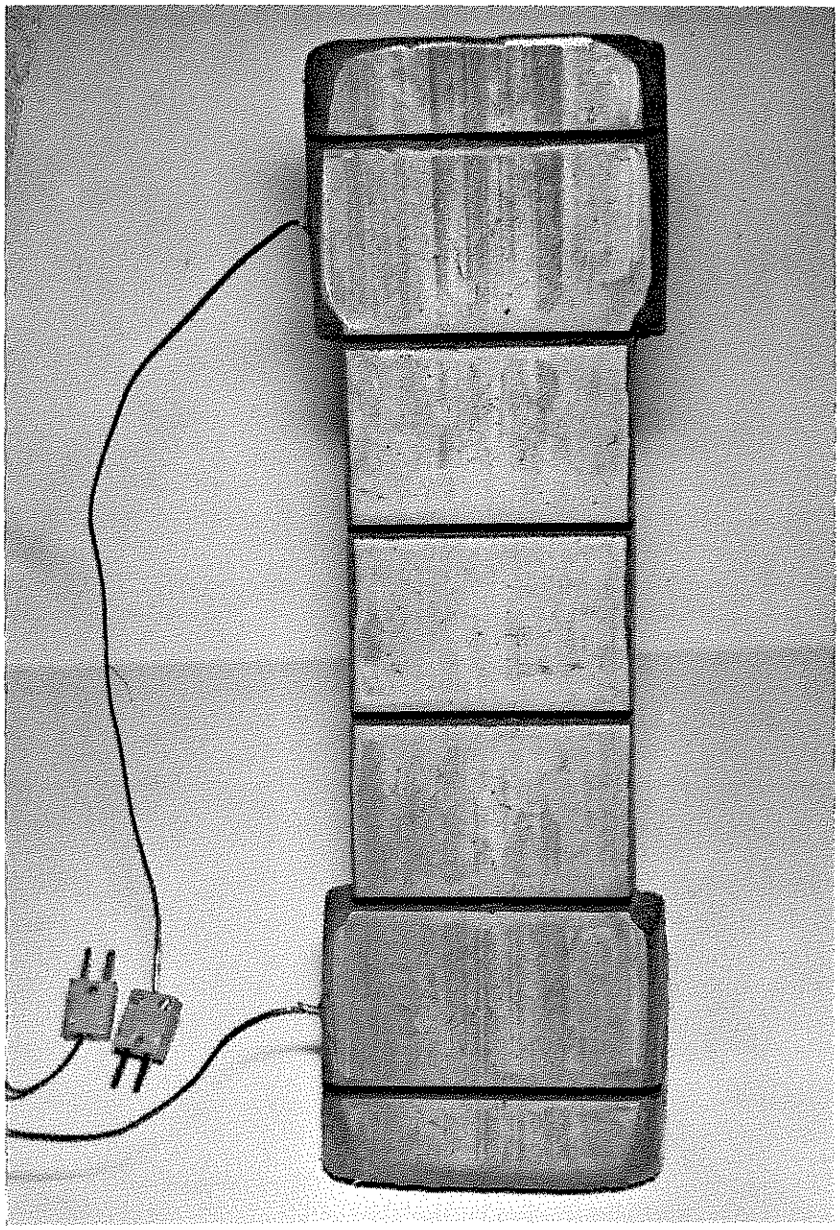

Fig. 3 Brake Shoe C-9

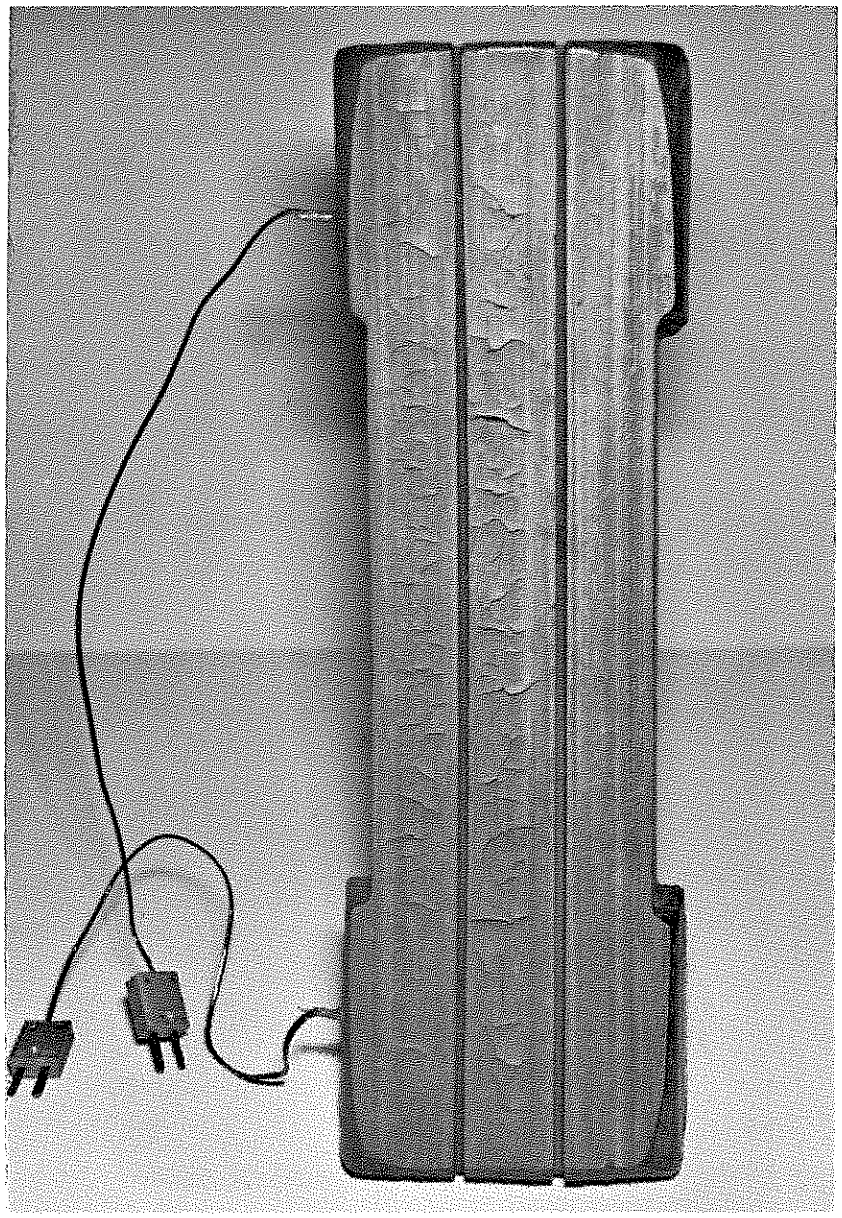

Fig. 4 Brake Shoe C-11

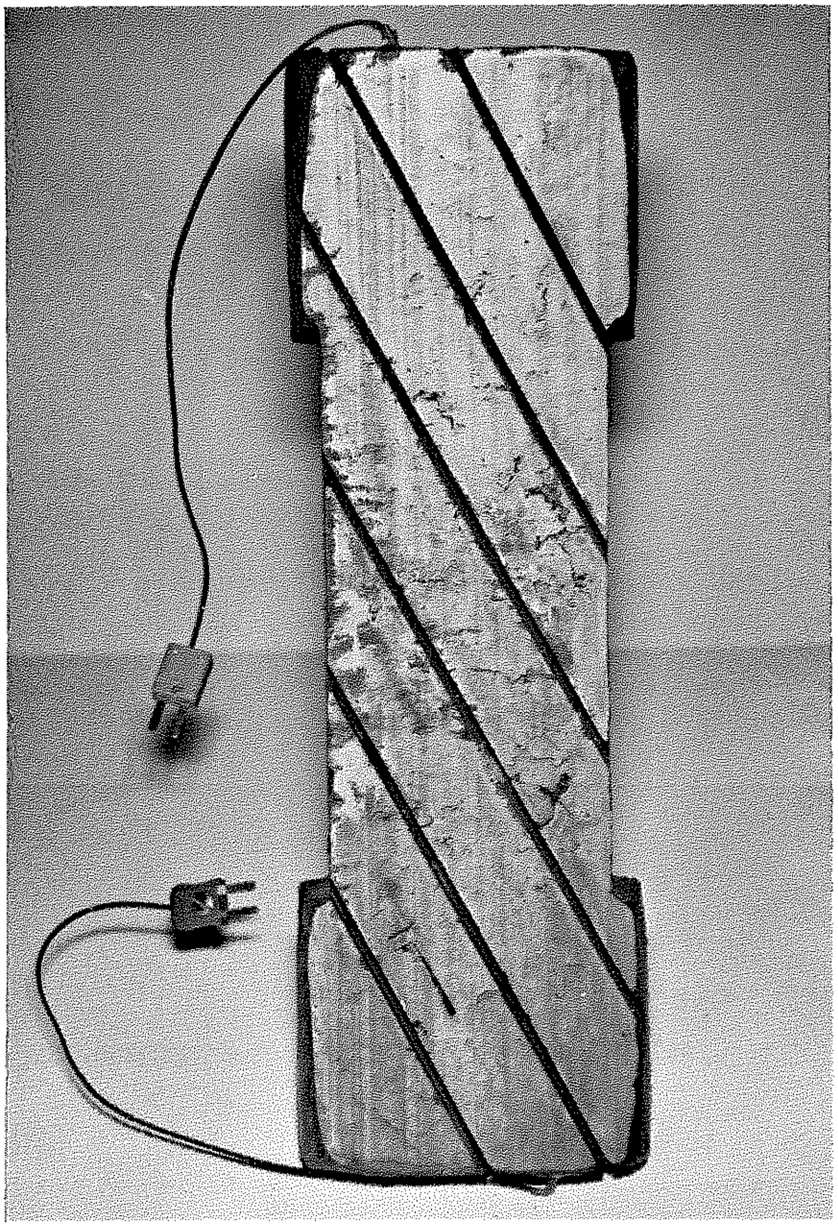

Fig. 5 Brake Shoe C-12

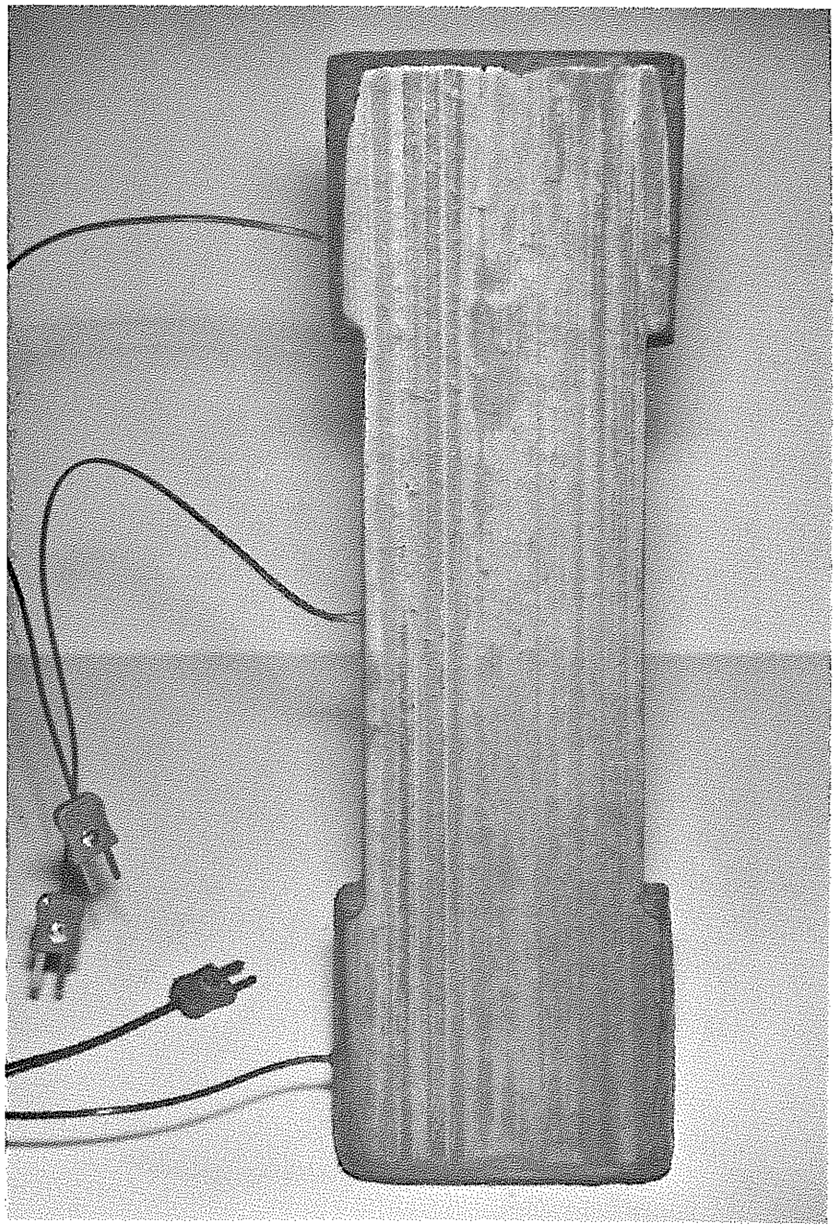

Fig. 6 Brake Shoe C-13

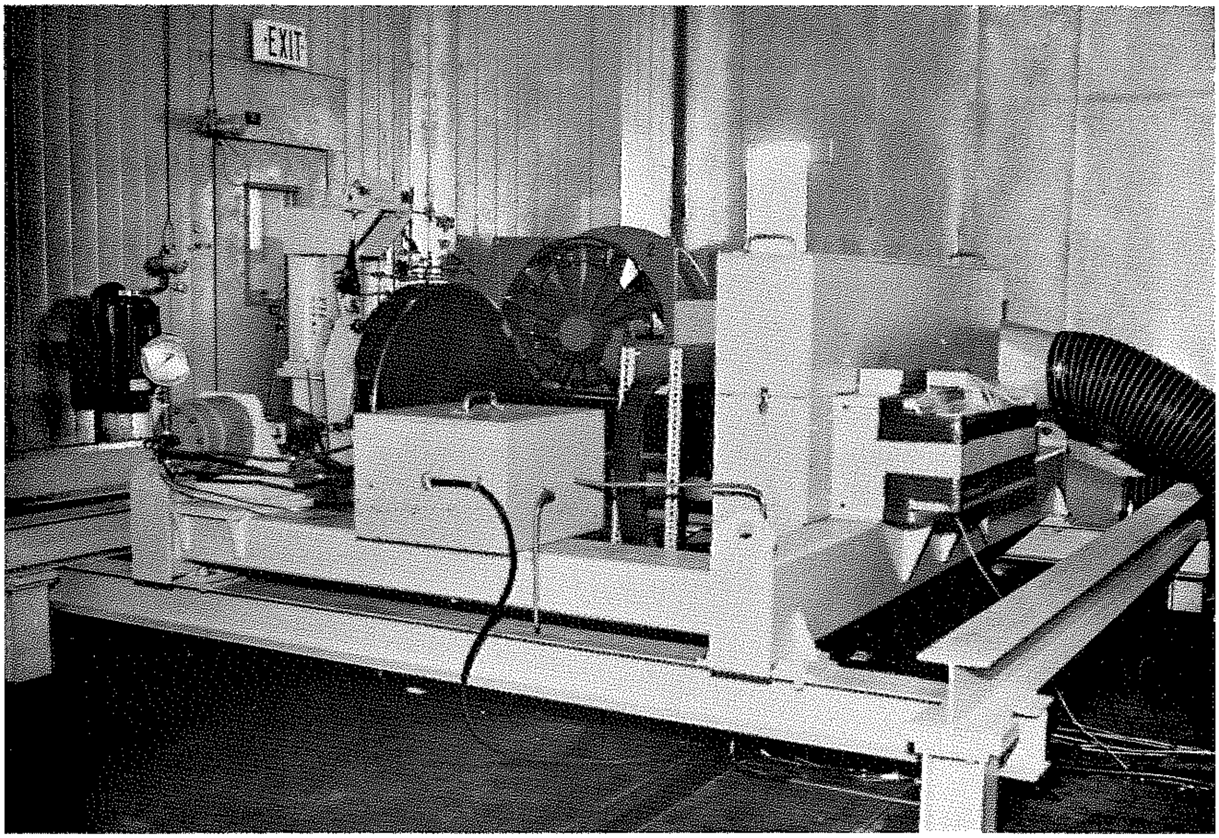

Fig. 7 Dynamometer Test Fixture

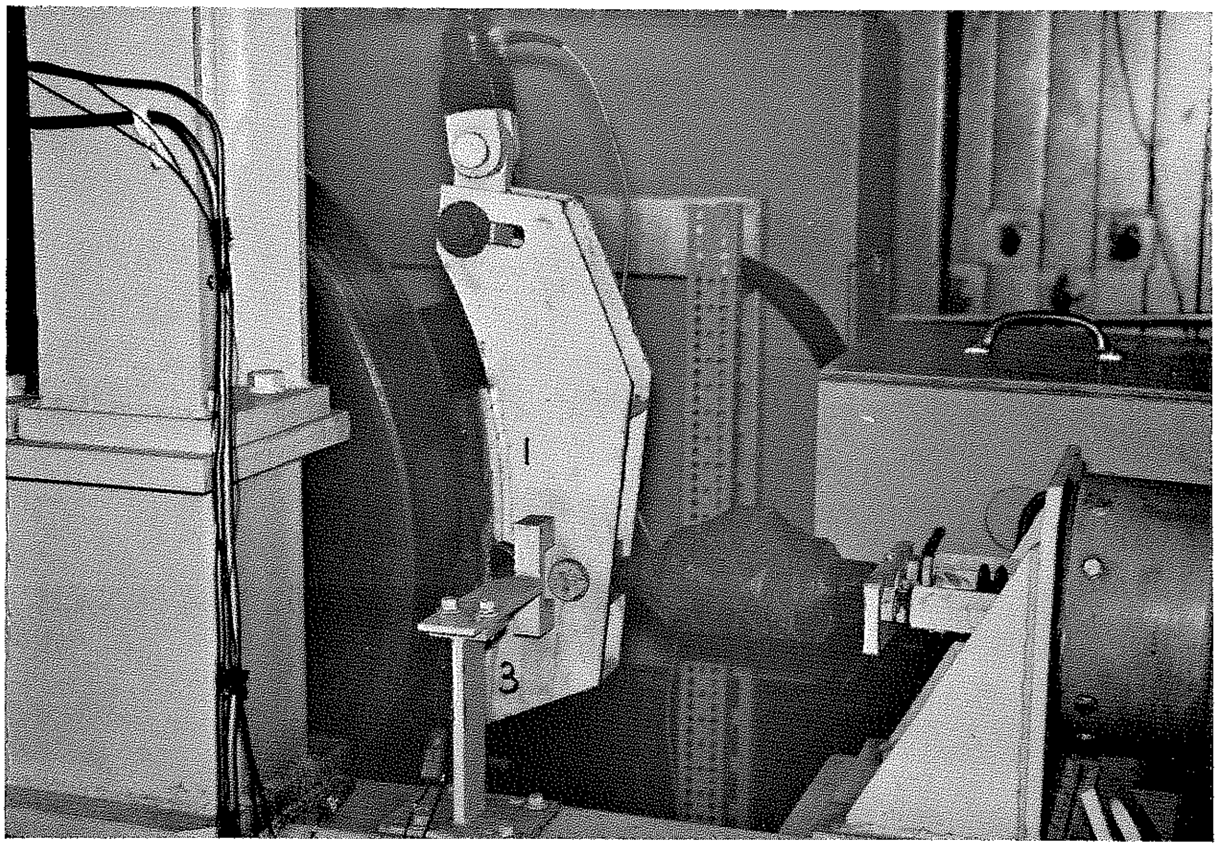

Fig. 8 Brake Shoe Carrier and Load Cells

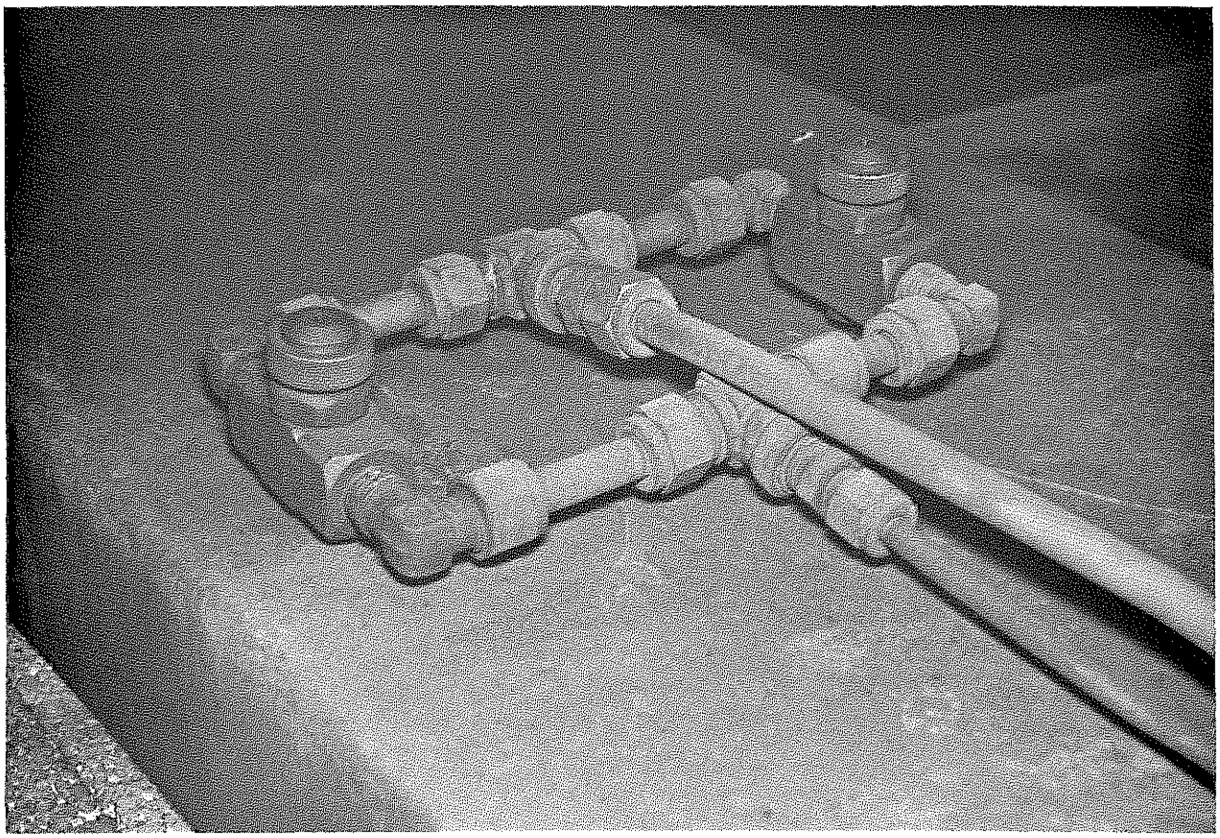

Fig. 9 Water Atomizing Nozzles

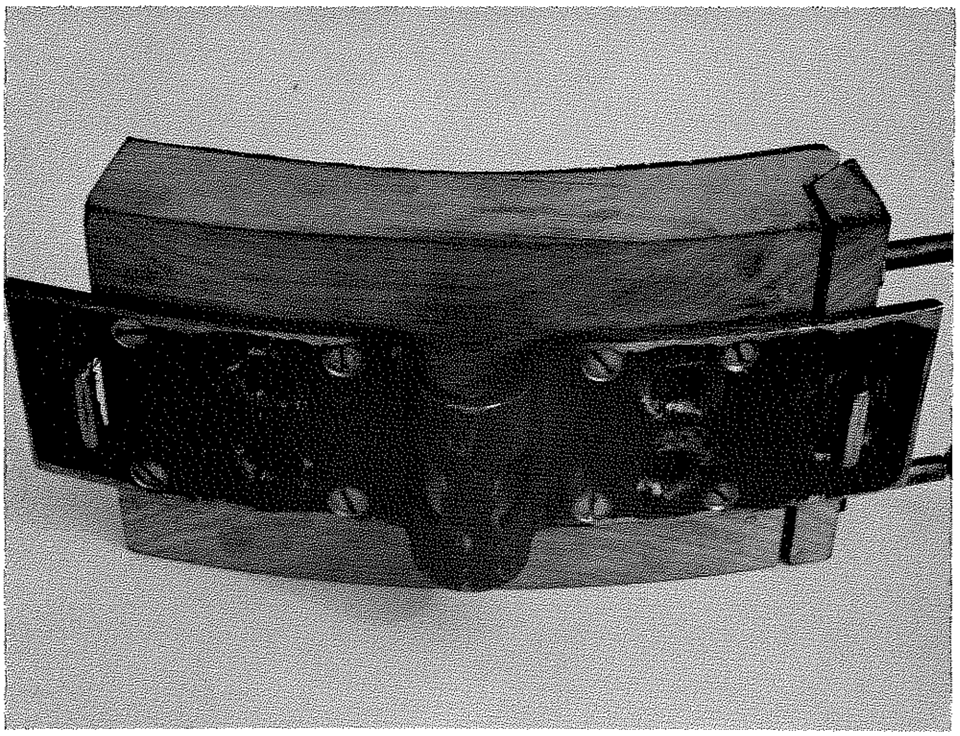

Fig. 10 Wheel Dressing Block

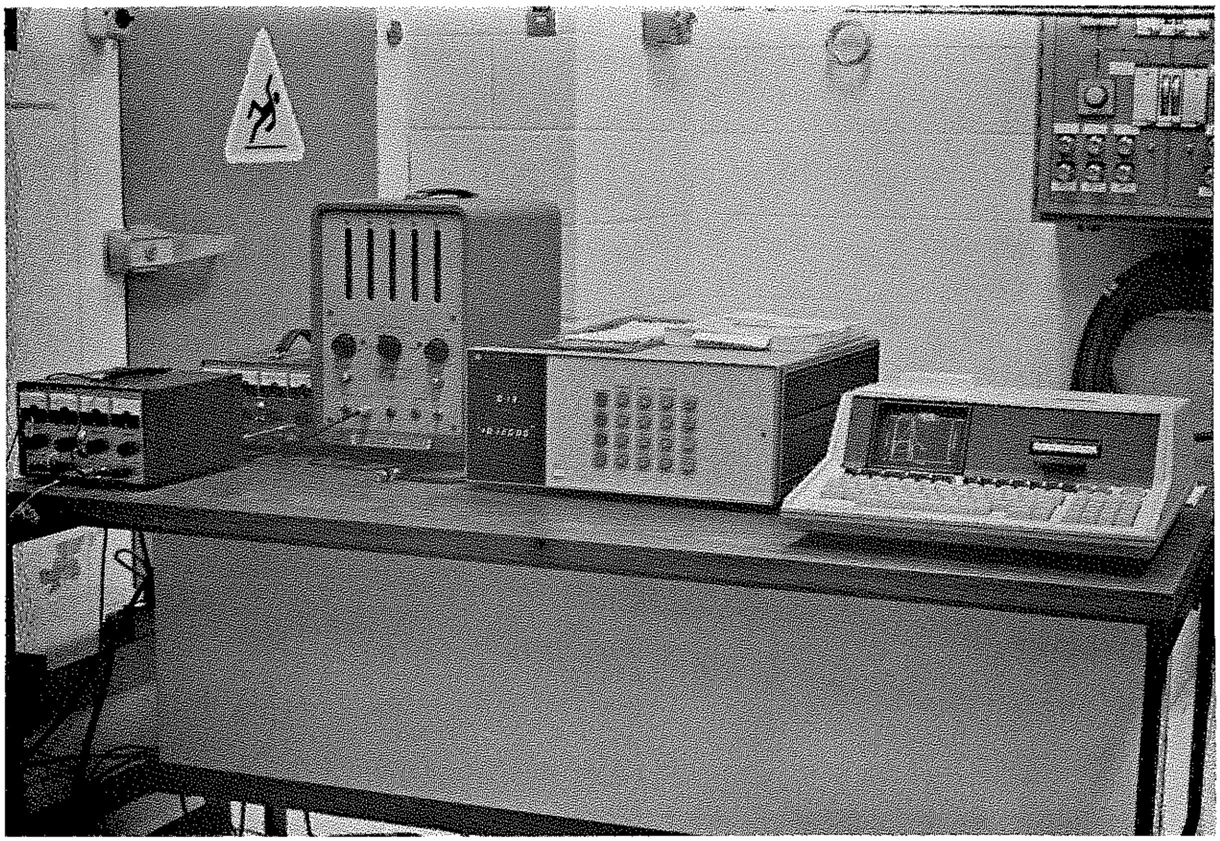

Fig. 11 Computerized Data Acquisition System

TABLE 1

Summary of Test Series

Test No.	Brake Shoe (code)	Test Type	Speed (mph)	Load (lbs)	Spray (ml/min.)
1-6	C-13	Pretest	30/50	1300	
7-12	C-9	Wet	30/50	1300	400
13-18	C-9	Wet	30/50	2000	400
19-24	C-9	Dry	30/50	1300	
25-30	C-9	Dry	30/50	2000	
31-36	C-11	Wet	30/50	1300	400
37-42	C-11	Wet	30/50	2000	400
43-48	C-11	Dry	30/50	1300	
49-54	C-11	Dry	30/50	2000	
55-60	C-12	Wet	30/50	1300	400
61-66	C-12	Wet	30/50	2000	400
67-72	C-12	Dry	30/50	1300	
73-78	C-12	Dry	30/50	2000	
79-84	C-13	Wet	30/50	1300	400
85-90	C-13	Wet	30/50	2000	400
91-96	C-13	Dry	30/50	1300	
97-102	C-13	Dry	30/50	2000	

TABLE 2

Summary of Dry Friction Tests

BSL (lbs)	Brake Shoe (code)	Friction Coefficient @ 30 mph	Friction Coefficient @ 50 mph
1300	C-9	0.368	0.342
1300	C-11	0.373	0.340
1300	C-12	0.378	0.366
1300	C-13	0.375	0.341
2000	C-9	0.344	0.350
2000	C-11	0.367	0.351
2000	C-12	0.386	0.366
2000	C-13	0.346	0.337

TABLE 3

Summary of Wet Friction Tests

BSL (lbs)	Brake Shoe (code)	Friction Coefficient @ 30 mph	Friction Coefficient @ 50 mph
1300	C-9	0.025	0.029
1300	C-11	0.035	0.038
1300	C-12	0.045	0.139
1300	C-13	0.027	0.033
2000	C-9	0.021	0.021
2000	C-11	0.030	0.034
2000	C-12	0.039	0.178
2000	C-13	0.021	0.022

Note: All wet friction tests were conducted with a water flow rate of 400 ml/min.

TABLE 4

Cylindrical Wheel Surface Roughness Measurements

A) PRIOR TO WHEEL SURFACE DRESSING:

Across Point "A"	Profilometer Reading (μ in.)
inboard 1 in.	20-30
inboard 2 in.	15-25 (one jump over 25)
centre	20-40
outboard 2 in.	20-35
outboard 1 in.	20-50

Across Point "B"	
inboard 1 in.	15-40
inboard 2 in.	10-25 (two jumps over 25)
centre	20-40 (one jump over 40)
outboard 2 in.	20-40
outboard 1 in.	20-50

B) AFTER WHEEL SURFACE DRESSING

Across Point "A"	Profilometer Reading (μ in.)
inboard 1 in.	5-12
inboard 2 in.	5-8
centre	5-10
outboard 2 in.	5-13
outboard 1 in.	5-14

Across Point "B"	
inboard 1 in.	5-12
inboard 2 in.	5-11
centre	7-13
outboard 2 in.	8-12
outboard 2 in.	5-11

APPENDIX A

EQUIPMENT

1. Motor	ASEA Type LAB 250 DC 150 HP, 1600 RPM Forced Air Cooled
2. Motor Control	BEEL Controls Ltd. SCR Adjustable Drive
3. Compression Load Cell	BLH Corporation Type U3G1 5000-pound capacity
4. Tension Load Cell	BLH Corporation Type U2M1 2000-pound capacity
5. Brake Cylinder	GRANNING Truck Suspension Ltd. #10-1080 Type 50
6. Data Acquisition/ Control Unit	HEWLETT-PACKARD Ltd. Model #HP-3497A
7. Computer	HEWLETT-PACKARD Ltd. Model #HP-85A
8. Speed Sensor	AIRPAX Electronics Magnetic Speed Sensor A 07355 Part No. 087-304-0002
9. Speed Indicator	HEWLETT-PACKARD Ltd. Model #5308A Timer-Counter
10. DC Excitation Sources	ANATEK Model 50-1.00 Dual Channel DC Power Supply
11. Surface Roughness Tester	AMPLIMETER PROFILOMETER Type Q Model 8 Handheld Skidmount LK4-3174 Micrometral
12. Wind Fans	SHELDON Engineering Ltd. 550 volts, Variable Speed #TD4746

REPORT DOCUMENTATION PAGE/PAGE DE DOCUMENTATION DE RAPPORT

REPORT/RAPPORT TR-LT-001 1a	REPORT/RAPPORT NRC No. 23707 1b
REPORT SECURITY CLASSIFICATION CLASSIFICATION DE SÉCURITÉ DE RAPPORT UNCLASSIFIED 2	DISTRIBUTION/DIFFUSION UNLIMITED 3

TITLE/SUBTITLE/TITRE/SOUS-TITRE (CLASSIFICATION) Unclassified
LABORATORY TESTING OF SLOTTED COMPOSITION BRAKE SHOES
4

AUTHOR(S)/AUTEUR(S)
Allard, F. C.
5

SERIES/SÉRIE
Technical Report
6

CORPORATE AUTHOR/PERFORMING AGENCY/AUTEUR D'ENTREPRISE/AGENCE D'EXÉCUTION
National Research Council of Canada Low Temperature Laboratory
Division of Mechanical Engineering
7

SPONSORING AGENCY/AGENCE DE SUBVENTION
8

DATE	FILE/DOSSIER	LAB. ORDER COMMANDE DU LAB.	PAGES	DIAGS	REFS
1984/08			27	11	3
9	10	11	12a	12b	12c

NOTES All values are not given in metric measurements since the North American railway industry still works mainly in Imperial units.
13

DESCRIPTORS(KEY WORDS)/MOTS-CLÉS
Brake shoe friction; hydroplaning; composition brake shoes
14

SUMMARY/SOMMAIRE
Wet and dry friction coefficients were measured for composition brake shoes with slots to establish whether this treatment reduced the hydroplaning effect.
15

ADDRESS/ADRESSE
T. R. Ringer, Head,
Low Temperature Laboratory,
Division of Mechanical Engineering,
National Research Council of Canada,
Montreal Road, Ottawa, Ontario.
K1A OR6 (613) 993-2439
16