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**Technical Report**

**Rapport Technique**

**1986/01**

**TR-LT-011**
**NRC NO. 25634**

# LABORATORY TESTING OF FOUR JAPANESE ANTI-SNOW RAILWAY BRAKE SHOES

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Canada

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# LABORATORY TESTING OF FOUR JAPANESE ANTI-SNOW RAILWAY BRAKE SHOES

# PERFORMANCE EN LABORATOIRE DE QUATRE SABOTS DE FREINS ANTI-NEIGE JAPONAIS

**D.E. Morris**

Technical Report

1986/01

Rapport technique

TR-LT-011
NRC NO. 25634

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Director/
Directeur

## ABSTRACT

The performance of four types of Japanese anti-snow railway brake shoes was investigated on a dynamometer to establish friction coefficients for two load conditions and two wheel speeds, in dry and wet weather conditions. The results were compared with the known performance of an AAR standard type composition shoe to determine whether any of them were effective in reducing hydroplaning during wet braking tests. In all wet tests the coefficient value was 0.04 or lower, and all shoes hydroplaned in a similar manner.

During dry friction tests with a sintered copper alloy shoe, eight cracks were formed around the circumference of the dynamometer test wheel ranging in depth from 0.95 to 6.1 mm.

## RÉSUMÉ

La performance au dynamomètre de quatre sabots de freins anti-neige japonais a été examinée afin d'évaluer les coéfficients de frottement sous conditions sèches et mouillées, en se basant sur deux charges différentes et deux vitesses de la roue.

Les résultats ont été comparés avec ceux d'étalon de AAR de sabot de frein fibré, afin de déterminer si, sous conditions mouillées, les sabots japonais pourraient réduire la fréquence de l'aquaplanage. On a trouvé que les coéfficients de frottement, sous conditions mouillées, étaient 0.04 ou moins. Tous les sabots ont aquaplané de manière similaire.

Durant les épreuves à sec avec un sabot de frein à l'alliage cuivreux et fritté, huit fissures se sont formées autour de la roue de dynamomètre. La profondeur de ces fissures a été de 0.95 à 6.1 mm.

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# LABORATORY TESTING OF FOUR JAPANESE ANTI-SNOW RAILWAY BRAKE SHOES

## 1.0 INTRODUCTION

The National Research Council of Canada has been involved, since 1981, with the study of the braking action of composition brake shoes for trains, and in their performance under adverse weather conditions. Two test programmes have been completed using standard shoes of various compositions or configurations. In both programmes it was found that all composition shoes exhibited hydroplaning under certain conditions. Hydroplaning is defined by the Association of American Railroads (AAR) as existing when an average coefficient of friction of less than 0.10 is produced during wet braking tests (Anderson, et al., 1983)

The first phase of tests (Ringer, 1983) was carried out using a dynamometer test fixture specially designed for brake shoe testing. Both wet and dry friction tests were conducted using a cylindrical rather than profiled test wheel. Emphasis was placed on careful and lengthy preparation of each brake shoe prior to testing in order to obtain a contact area between the shoe and wheel surface of at least 80%. The report on this phase concluded that all the composition shoes hydroplaned in wet braking conditions.

In an attempt to improve braking and to reduce hydroplaning, a second test phase (Allard, 1984) was performed with a set of composition shoes in which various types of slots were machined. The test objective was to determine how the slotted shoes would perform in comparison with unmodified reference shoes. Friction coefficient values obtained indicated that there was no significant difference between them in either wet or dry tests.

A Canadian railway delegation visited Japan in 1983, under Transport Canada sponsorship (Bach,et al., 1983). As a result of discussions of research activities pertaining to brake shoes, arrangements were made for four types of Japanese railway freight car anti-snow shoes to be provided to NRC for test purposes. This report presents the results of their performance during wet and dry friction tests in direct comparison with one standard AAR type composition shoe.

## 2.0 TEST FIXTURE

All tests were done on the same dynamometer fixture used in both earlier phases, with its special cylindrically machined 88 cm diameter freight car wheel and axle set. The test apparatus consisted of a 600-volt, 3-phase AC source, with suitable transformer, rectified to supply power to a 110 kW 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 along side 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. A compression load cell was fastened between the air cylinder actuator and the brake shoe carrier to measure normal force. Figure 1 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 are shown in more detail in Figure 2.

A computer-based data acquisition system was utilized to collect test data, as seen in Figure 3. The computer program allowed 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 off-sets 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

Preparation of the brake shoes started with machining to match the radius of the cylindrical test wheel. After machining, two copper-constantan thermocouples were installed in each shoe at a depth of 6 mm below the contact surface and on the longitudinal centreline of the brake shoe.

Preliminary wear-in was then carried out on a special grinding fixture to reduce the period of time needed to obtain 80 percent contact between wheel and brake shoe. This fixture enabled final shaping of the shoe to the wheel surface but, because of surface variations in the wheel, the wear-in process required much hand filing and fitting. During wear-in, a large amount of heat energy was produced and both wheel and shoe temperatures increased rapidly. To prevent thermal damage, it was necessary to keep brake applications short and to use forced air cooling between applications. Wear-in often took several days for each shoe.

After wear-in, and also after brake shoe tests, it was necessary to clean the wheel surface carefully in order to maintain a 250 to 500 nm surface finish. This was done using a specially designed hardwood dressing block, shown in Figure 4, and different grades of abrasive paper. The wheel surface was visually examined and measured with a roughness tester, usually before and after testing of each type of brake shoe. Table I lists readings taken across the face of the wheel at two arbitrarily assigned positions.

## 4.0 TYPES OF BRAKE SHOES TESTED

Synthetic railway brake shoes, made of composite friction materials, were first used in Japan in 1958 and the realization of 120 km/h operation in 1968 was due in part to their adoption. Idemura reported that, when coaches fitted with the new type shoes began operating in snowy areas, a decrease in braking effectiveness was noted during snowfalls and in snow accumulation environments (Idemura, 1981). To counter this problem, it was decided to develop synthetic brake shoes capable of breaking the water layer at the shoe/wheel interface, and of preventing the drop in friction coefficient which the hydroplaning phenomenon exhibits.

Numerous combinations of materials harder than the wheel itself were mixed with various friction compounds. Basic patterns were defined and in 1973 the synthetic anti-snow brake shoe was JRS (Japan Railway Standard) type certified. Development has continued to find solutions to the problem of how to improve materials and to minimize damage and abrasion to wheels.

In 1983 a Canadian railway delegation visited Japan and members had an opportunity to discuss research activities pertaining to brake shoes. It was considered advisable to acquire some specimen JNR (Japan National Railways) anti-snow shoes for laboratory testing at NRC, as part of ongoing investigations into brake shoe performance under adverse weather conditions. At the request of Mr. R. Klein of Canadian Pacific, Mr. P.L. Eggleton, Counsellor for Science and Technology of the Canadian Embassy in Tokyo, arranged for sample quantities of four types to be prepared on AAR standard backing plates and shipped to Canada. Two shoes of each type were sent to NRC where they were given individual code identifiers. A description of the four shoe types and the Cobra composition standard reference shoes is given below.

| CODE | SHOE TYPE | MANUFACTURER |
|---|---|---|
| 1JA,1JB | Dispersion | - Uedasa-Chuzosho. Ltd. |
| 2JA,2JB | Sintered | - Akebono Brakes Industry Co. Ltd. |
| 3JA,3JB | Homogeneous Dispersion | - Akebono Brakes Industry Co. Ltd. |
| 4JA,4JB | Insertion | - Nippon Shingo Co. Ltd. |
| C13,C14 | Composition | - Wabco - Cobra |

### 4.1 Dispersion Type Shoes - 1J (A and B)

The contact surfaces of both samples were machined to match the radius of the test wheel. These machined surfaces revealed dull, brass coloured bodies in a darker matrix speckled with small reflective particles [Fig. 5]. Hardness measurements were made at random on the dispersion particles, and the surrounding matrix and the values are listed in Section 4.6. The 1JA shoe was prepared for testing while 1JB was held in reserve.

### 4.2 Sintered Alloy Shoes - 2J (A and B)

Both shoes were machined to the appropriate radius. The exposed surfaces were bronze coloured with a dappled, slightly porous texture [Fig. 6]. Hardness measurements were made and recorded and an attempt was made to prepare the 2JA shoe for testing. It soon became apparent that much work would be needed to attain 80% contact and so the 2JB was tried. It proved to be acceptable for testing.

### 4.3 Composite Homogeneous Shoes - 3J (A and B)

Examination of the machined surface of these shoes showed that there were two kinds of light coloured particles dispersed randomly in a darker matrix. One particle was generally angular in shape and had a brassy shine, while the other was more circular with a sandy grey texture [Fig. 7]. Rockwell hardness measurements were made before brake tests were started on the 3JA shoe.

### 4.4 Insertion Type Shoes - 4 J (A and B)

Machining disclosed four lozenge shaped inserts approximately 3 cm x 6 cm in size, regularly spaced in the shoe body. They were grey coloured with white particles and, on a machined surface, were more reflective than the surrounding dark grey matrix material [Fig. 8]. Rockwell hardness tests were made on the insert and matrix material and are discussed in Section 4.6. The 4JA shoe was prepared for testing.

### 4.5 Cobra Composition Shoes - C13 and C14

A Wabco Cobra composition shoe, designated C13, [Fig. 9], which had been used in a previous test series (Allard, 1984), was again used as the reference standard. During the programme another Cobra shoe, C14, from recent production was tested for comparison purposes. Hardness measurements were also made and are tabulated in Section 4.6.

### 4.6 Hardness Measurements

The hardness of the machined shoe surfaces were measured in two series of tests; one, on the Rockwell B scale, with a 1.6 mm diameter penetrator and 100 kg load, and the second, on the Rockwell E scale, with 3.2 mm diameter penetrator and 100 kg load. For those shoes with particles dispersed in a surrounding matrix, readings were taken on both materials.

**SUMMARY OF HARDNESS MEASUREMENTS**

| Shoe Type | Rockwell B hardness 1.6 mm Dia. Ball, 100 kg penetrator (Nanometres) | Rockwell E Hardness 3.2 mm Dia. ball, 100 kg penetrator (Nanometres) |
|---|---|---|
| 1J(A and B) | 890<br>1020<br>1270<br>890<br>740<br>300 | 1120<br>1730 |
| 2J(A and B) | 460<br>0<br>-130<br>610<br>280<br>-30 | 1300<br>510 |
| 3J(A and B) | -30<br>-50 | 360 |
| 4J(A and B) | 280<br>640<br>380<br>300<br>460<br>300 | 1040<br>1750 |
| Cobra | 300 | - |

## 5.0 TEST PROCEDURE

For all of the brake shoe performance tests, each shoe was tested at speeds of 50 km/h and 80 km/h, and at two load conditions for each speed. A maximum load of 8900 Newtons could be sustained by the motor drive and was chosen for the high setting. A load of 5800 Newtons was chosen for the low setting. As well, the chamber temperature was maintained at approximately 15°C and the wheel temperature lowered to 20°C 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.

### 5.1 Dry Tests

During the dry friction tests, as many as seven 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. 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 the 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.

### 5.2 Wet 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 (Ringer, 1983) 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 (Brown, 1973). At a maximum speed of 80 km/h for a 15 cm wide, 90 cm 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 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 10. 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.

### 5.3 Order of Testing

Brake testing invariably results in abrasion of the surface of the test wheel. The more abrasive the shoe the greater the damage that will be done to the wheel. Of the four Japanese anti-snow brake shoes used in this series, three were designed with coarse friction surfaces which, theoretically, would break down the water layer causing hydroplaning. In those three, materials harder than the wheel itself were mixed with composition friction material in various patterns. The fourth shoe was made of a sintered metal alloy.

It was decided to test the least abrasive shoe to start the programme and end with the most abrasive. Hardness measurements listed in Section 4.6 were used as the criteria for selecting the order of testing shown below.

| TEST ORDER | SHOE | ROCKWELL 'E' |
|---|---|---|
| 1 | 3JA | 360 |
| 2 | 2JB | 510-1300 |
| 3 | 1JA | 1120-1730 |
| 4 | 4JA | 1040-1750 |

The Cobra composition shoe, C13, was used as a reference standard and tested at various times during the programme to verify that the procedure and test apparatus were yielding valid data.

## 6.0 DISCUSSION OF RESULTS

All 503 dry and wet friction tests conducted during this investigation are listed in Table 2, which provides data on the brake shoe tested, type of test, speed and load settings, and, for the wet tests the water flow rate supplied. Explanatory notes provide brief descriptions of events during the programme. Because the test apparatus was located in a multi-purpose environmental chamber, the tests could not be run as one continuous series. Interruptions occurred when the chamber was used for other cold temperature work during the period of November 1984 to October 1985. An additional delay resulted when the wheel set had to be removed from the test bed, and the cylindrical wheel machined to remove surface cracks found at the conclusion of dry tests with the 2JB sintered metal shoe.

The interruptions necessitated many additional tests with the standard Cobra reference shoe to verify that the method and instrumentation provided valid results, and to prove that results from shoe to shoe could be correlated. Table 3 summarizes the coefficient of friction (COF) determined for the C13 Cobra shoe, in wet and dry conditions. Only minor deviations are noted and these may be attributed to the limited number of tests performed.

### 6.1 Dry Tests

Table 4 contains the results of dry friction tests for each Japanese shoe, the average for the C13 Cobra shoe, and values for the new production C14 shoe. At 5800 Newtons load, the average COF for all Japanese shoes was 0.41 at 50 km/h, and 0.33 at 80 km/h. The best performance was from the 1JA type (0.44 and 0.35). With 8900 N load, the respective values at 50 and 80 km/h were 0.39 and 0.33, with the 2JA judged to be best at 0.43 and 0.32. Overall, at 50 km/h, the Japanese shoes had COF values equal to or better than both Cobra samples but at 80 km/h there was little performance difference.

During dry friction tests with the 2JB shoe, each brake actuation was accompanied by high-pitched, squealing noises. At the conclusion of that series, the wheel surface was cleaned and examined prior to making surface roughness measurements. Eight surface cracks, ranging in length from 9 to 36 mm, were found distributed around the circumference of the wheel, as shown in Figure 11. These cracks had to be removed before continuing with the test programme. If they were sufficiently shallow, it would be possible to grind the wheel surface in situ. If, however, the cracks were deeper than a few tenths of a millimeter, then the wheel set would have to be removed from the rig and machined in a large capacity lathe.

The Engineering Physics Group of the NAE Structures and Materials Laboratory (NRC) was asked to inspect the wheel using nondestructive testing techniques to determine the depth of the cracks so that a decision on repair strategy could be made. Dye penetrant testing was selected to detect and locate surface breaking cracks. Figure 12 shows one crack before and after application of dye penetrant. Ultrasonic surface wave techniques were used to obtain estimated crack depths ranging from 0.7 to 5.7 mm and a decision was then made to remove the wheel set for remachining. The NAE evaluation was reported in a proprietary report, LTR-ST-1536 (Fahr, et al., 1985).

During the machining operation, the cracks were re-examined and measured after every cut, until they were no longer detectable. Actual crack depths ranged from 0.95 to 6.1 mm which agreed, within estimated errors, to the values determined by the nondestructive techniques. Idemura states that sintered alloy brake shoes are more liable to cause heat cracks than composite shoes and, generally, that the cracks are not deep, but in some cases small cracks developed into an exfoliation of the wheel tread (Idemura, 1981).

### 6.2 Wet Tests

Table 5 contains a summary of COF values for Cobra and Japanese shoes tested using the wet spray conditions specified in Section 5.2. No significant differences were found at any speed or load combinations. At 5800 N load the COF was between 0.04 and 0.02 at 50 and 80 km/h. There was a decrease to 0.03 and 0.01 at 8900 N. In other words, all the shoes hydroplaned in a similar manner under similar conditions.

### 6.3 Comparison with Previous Test Data

Table 6 was compiled from data reported in the two previous NRC programmes mentioned in the Introduction (Ringer, 1983 and Allard, 1984). Both wet and dry COF values show little variation within their set and thereby provide verification that the method was capable of producing reliable results over prolonged test periods.

## 7.0 CONCLUSIONS

The data collected during this test programme are good and reliable as verified by comparison to the standard reference shoe, previous results, and engineering judgement.

In dry braking conditions, at 50 km/h, all four Japanese shoes had COF values equal to or greater than Cobra composition shoes at both low and high test loads. There was little performance difference between them at 80 km/h.

The fact that sintered copper alloy brake shoes can cause cracks in railway wheel treads has been reported by various sources. The additional fact that they can be produced by a limited number of brake applications of short duration, at moderate speeds and brake pressures, was clearly shown during this programme. Their occurrence also exemplified the value of quantitative testing of brake shoes and braking actions.

All four Japanese anti-snow brake shoes hydroplaned under wet conditions and did not perform better than Cobra composition shoes. The wet tests, although not necessarily realistic in comparison with actual field conditions, enabled a comparison to be made among brake shoes and thus satisfied the objective of the programme.

Constraints imposed by other test projects limited the scope of this one to testing only in standard wet and dry conditions. No work was possible in simulated snow environments or in evaluating the performance of various brake application techniques. These are areas of study for future testing, preferably in a facility that would permit an uninterrupted, and thus more economical, programme to be run.

## 8.0 REFERENCES

ANDERSON, G.B., W.P. MANOS and N.G. WILSON 1983. Brake Shoe Performance Test II. Association of American Railroads. 1982-83 Pueblo, Colorado Test Series. Report R-565A:76.

RINGER, T.R. 1983. Railway Composition Brake Shoes - Laboratory Performance Tests - Phase 1. National Research Council Canada, Division of Mechanical Engineering. Report LTR-LT-143:22.

ALLARD, F.C. 1984. Laboratory Testing of Slotted Composition Brake Shoes. National Research Council Canada,Division of Mechanical Engineering. Report TR-LT-001:27.

BACH, C., A.E. BETHUNE, R. MANGHAN, V.W. SHTENKO, and D.E. WELSH 1983. Study of Advanced Technology on Japanese National Railways. Prepared for Transport Canada, Transportation Development Centre, Montreal.

IDEMURA, Yo. 1981. Anti-Snow Brakeshoes. Railway Technical Research Institute, Braking Systems Research Division. Japan:22.

BROWN, E.N. 1973. A Flowmeter to Measure Cloud Liquid Content. Atmospheric Technology No. 1:49-51

FAHR, A., A.R. KOTANEN, and A.M. CHARLESWORTH 1985. Non Destructive Evaluation of Surface Cracks in a Railway Brake Shoe Test Wheel. National Research Council Canada, National Aeronautical Establishment. Report LTR-ST-1536 (proprietary):7

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4 LABORATORY TESTING OF FOUR JAPANESE ANTI-SNOW RAILWAY BRAKE SHOES

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5 D.E. Morris

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6 Technical Report

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NOTES

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DESCRIPTORS(KEY WORDS)/MOTS-CLÉS

Brake Shoe friction of hydroplaning of Japanese brake shoes.

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SUMMARY/SOMMAIRE

Friction coefficients were measured for four types of Japanese anti-snow brake shoes and compared with AAR standard composition shoes to establish whether any of them were effective in reducing hydroplaning during wet braking tests.

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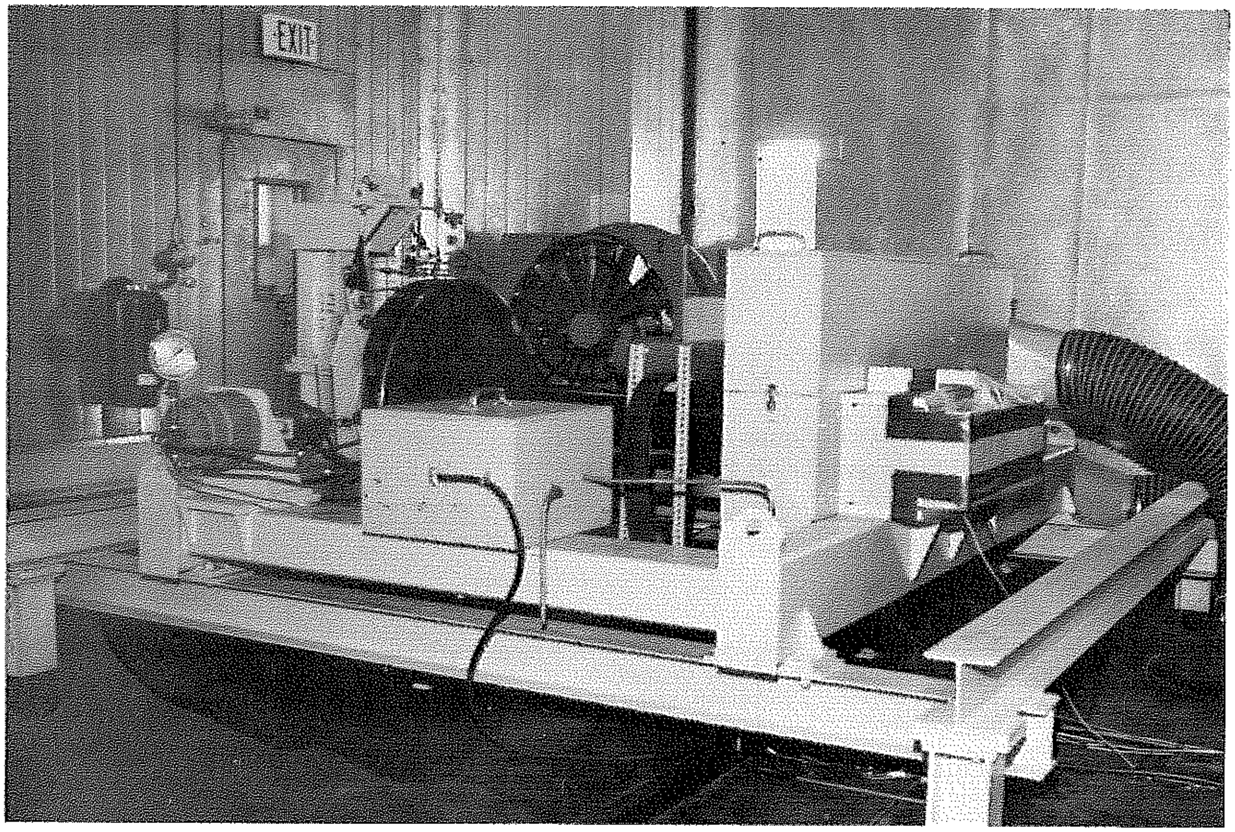


Fig. 1 Dynamometer Test Fixture

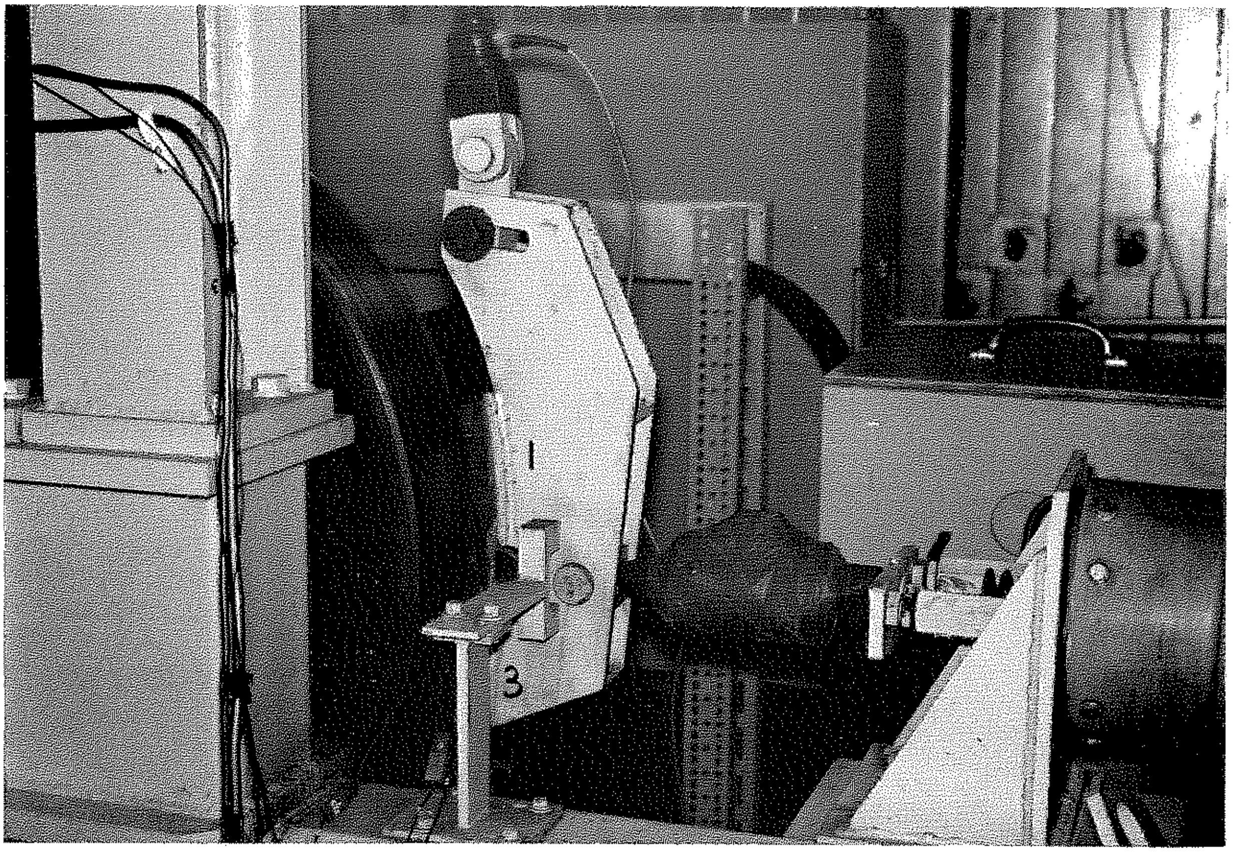

Fig. 2 Brake Shoe Carrier and Load Cells

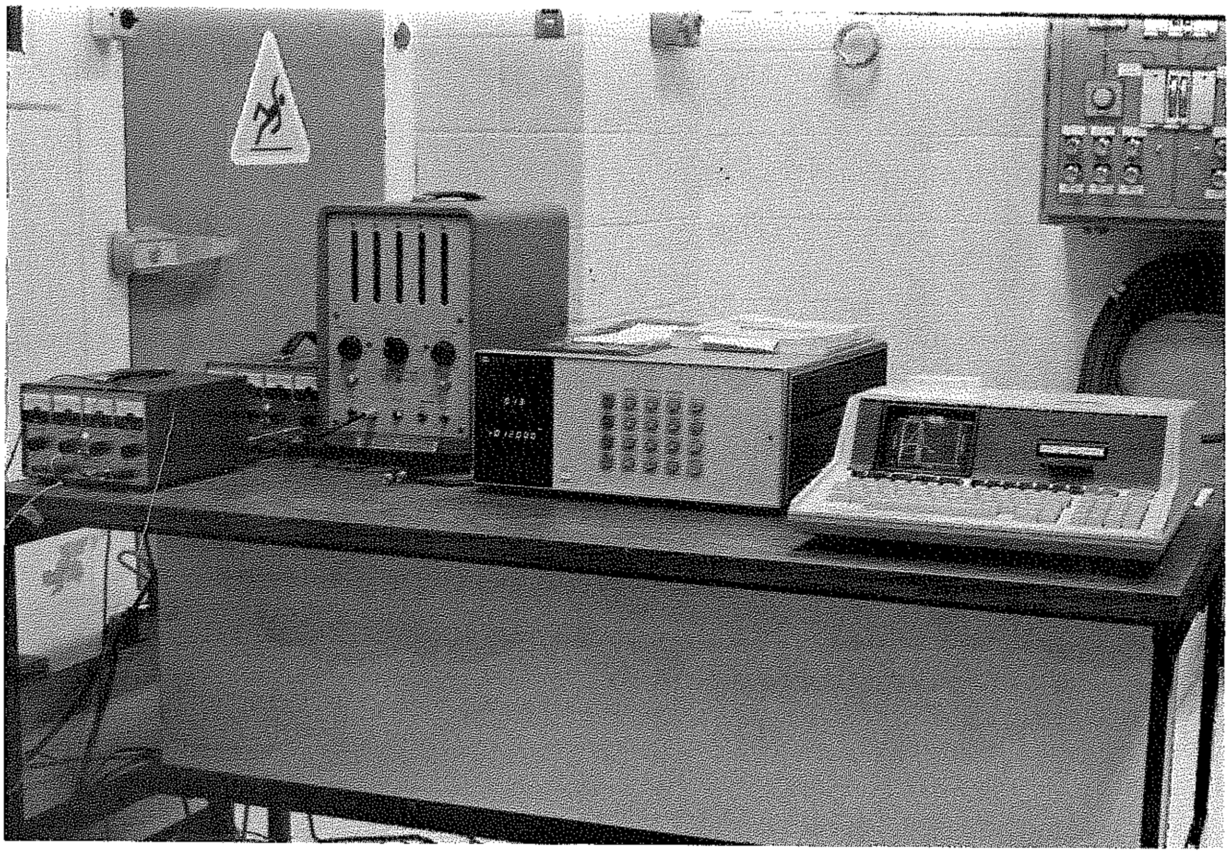

Fig. 3 Computerized Data Acquisition System

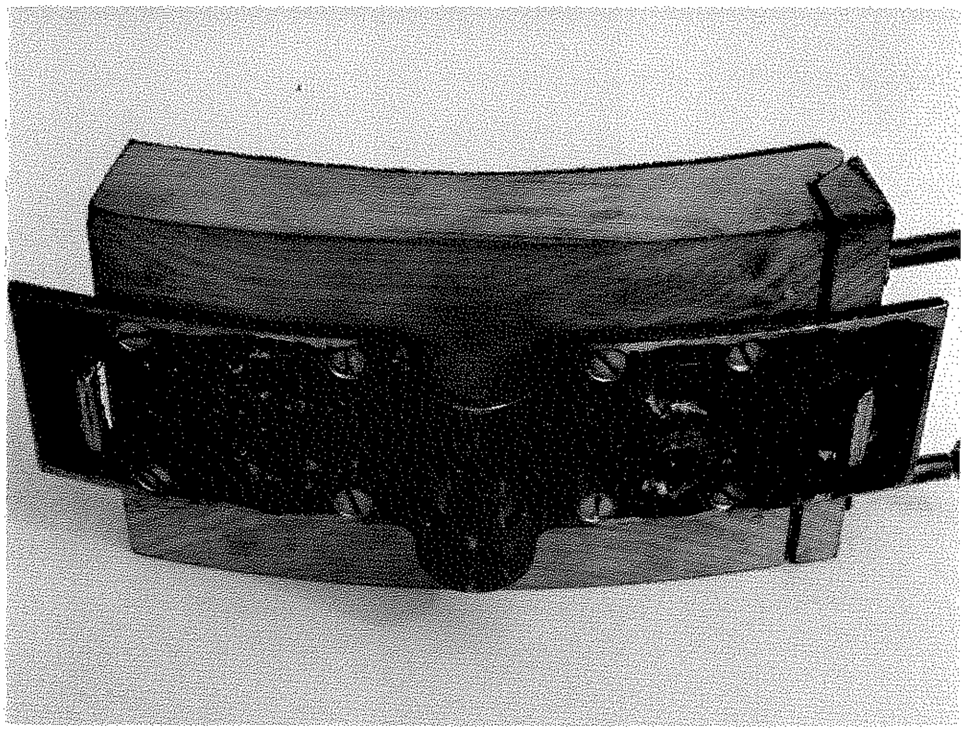

Fig. 4 Wheel Dressing Block

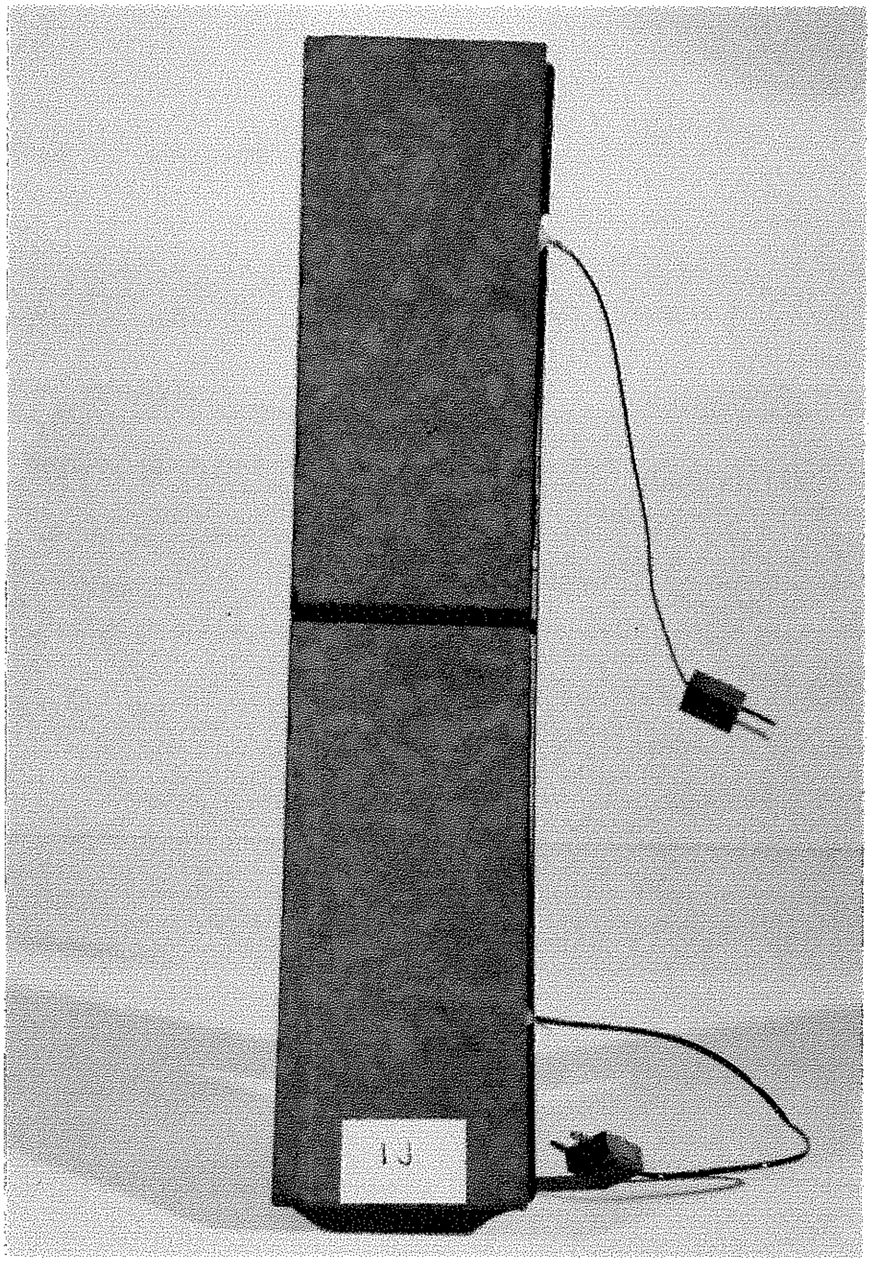


Fig. 5 Dispersion Type Shoe - 1J

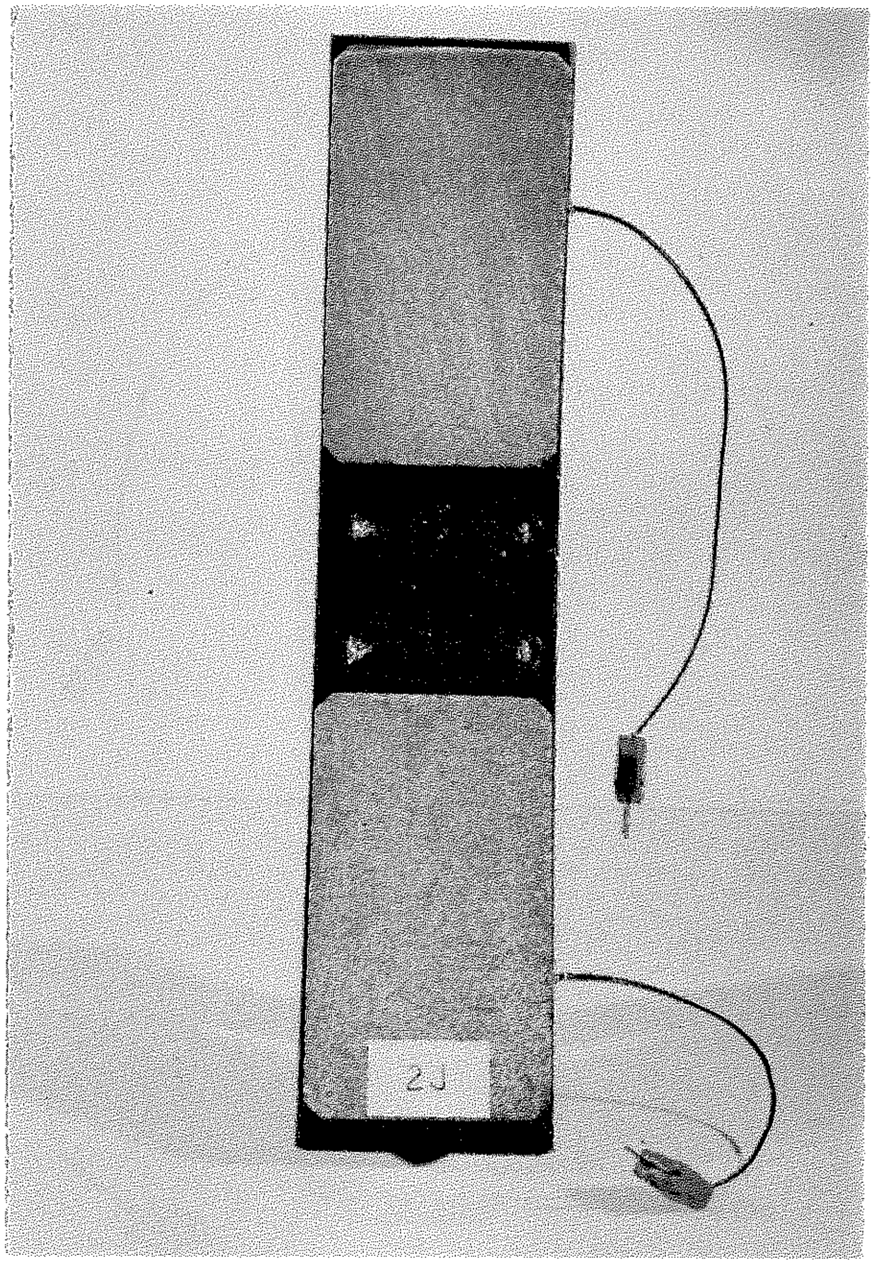


Fig. 6 Sintered Alloy Shoe - 2J

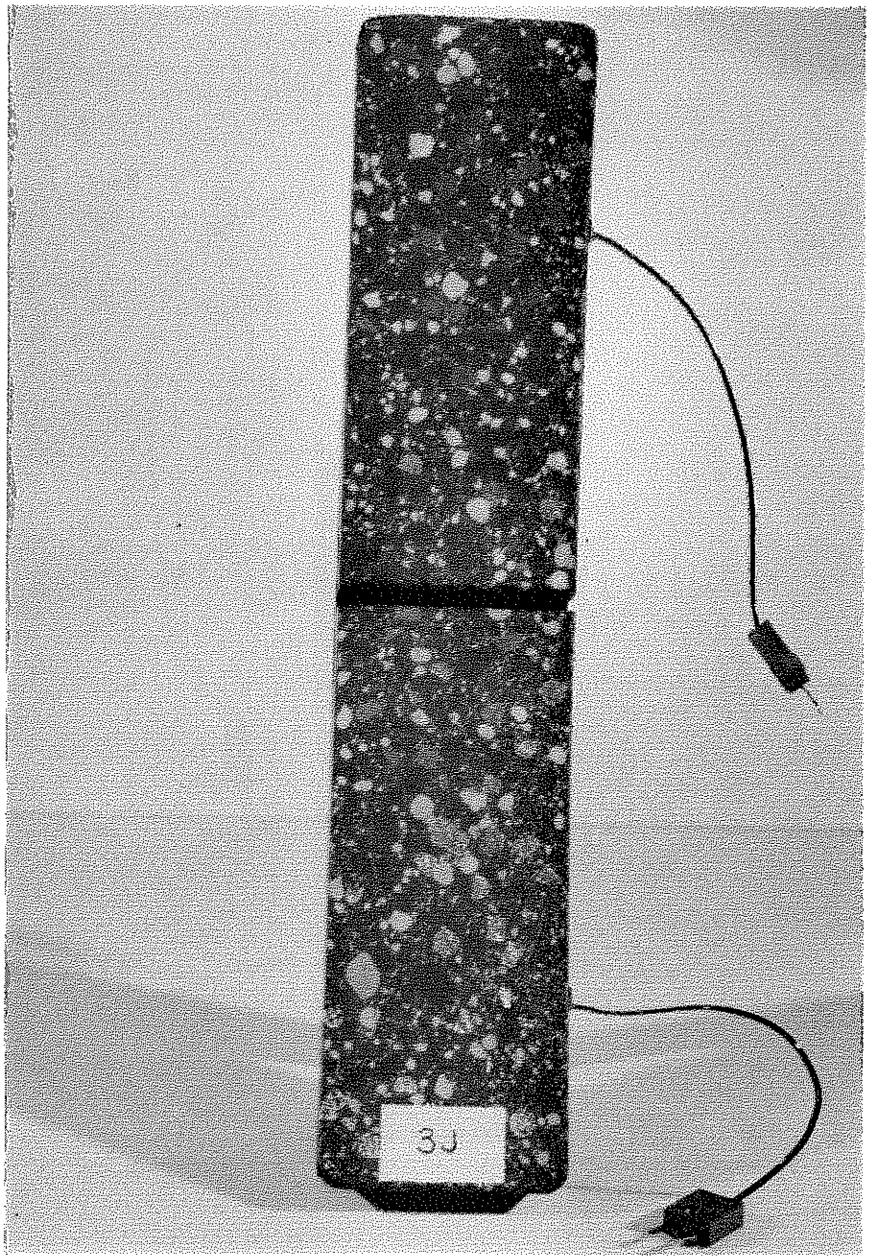


Fig. 7 Composite Homogeneous Shoe - 3J

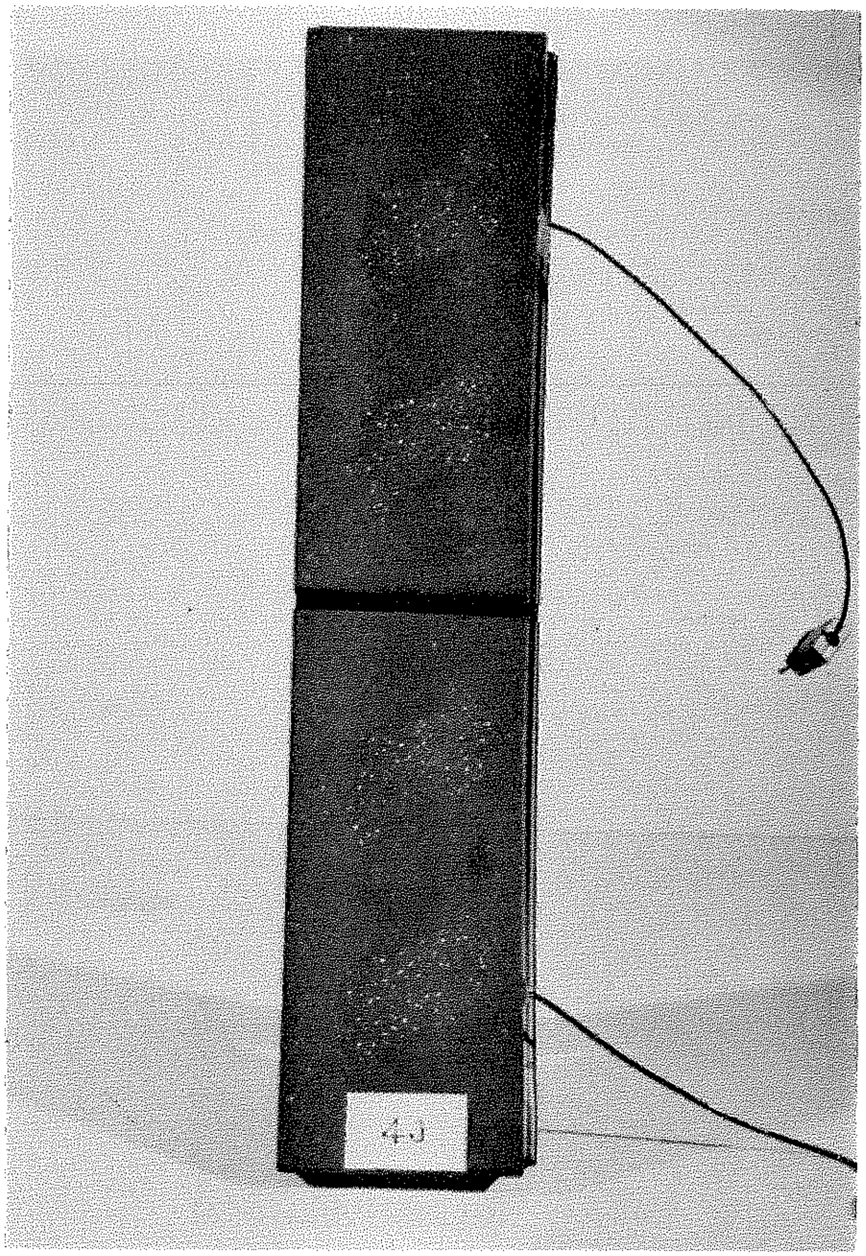


Fig. 8 Insertion Type Shoe - 4J

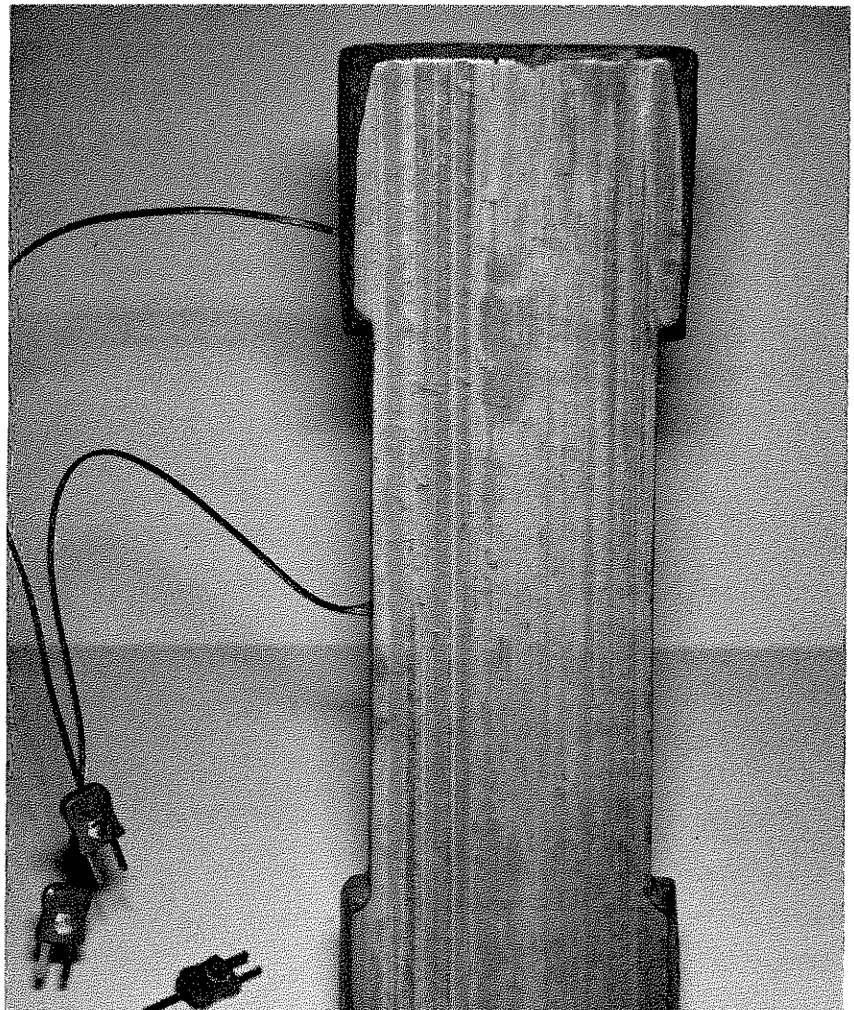

Fig. 9 Brake Shoe C-13

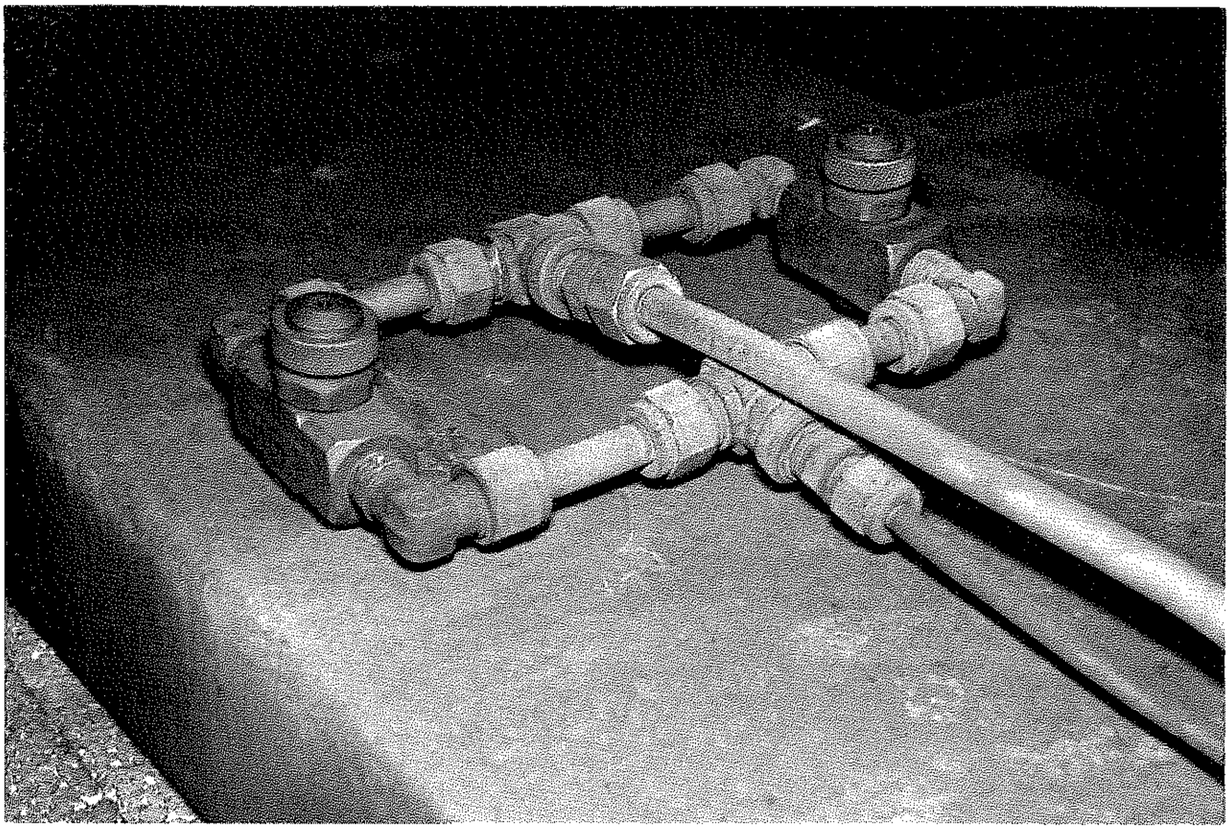

Fig. 10 Water Atomizing Nozzles

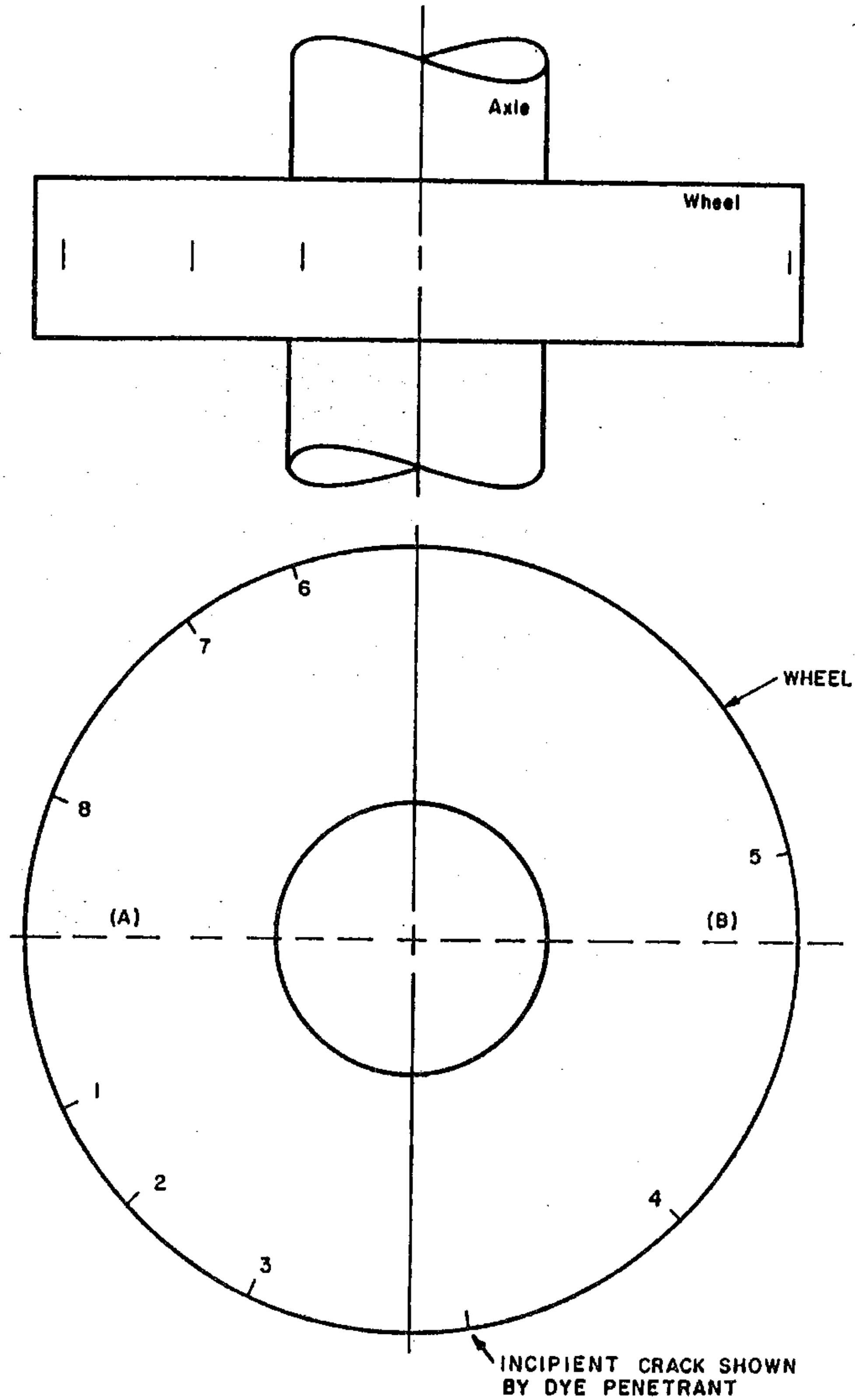


Figure 11 Location of surface cracks on the test wheel

Note: Locations A and B were arbitrarily assigned to facilitate identification of individual cracks. The cracks are distributed around the wheel circumference and are all transverse in character with lengths ranging from 9 to 36 mm.

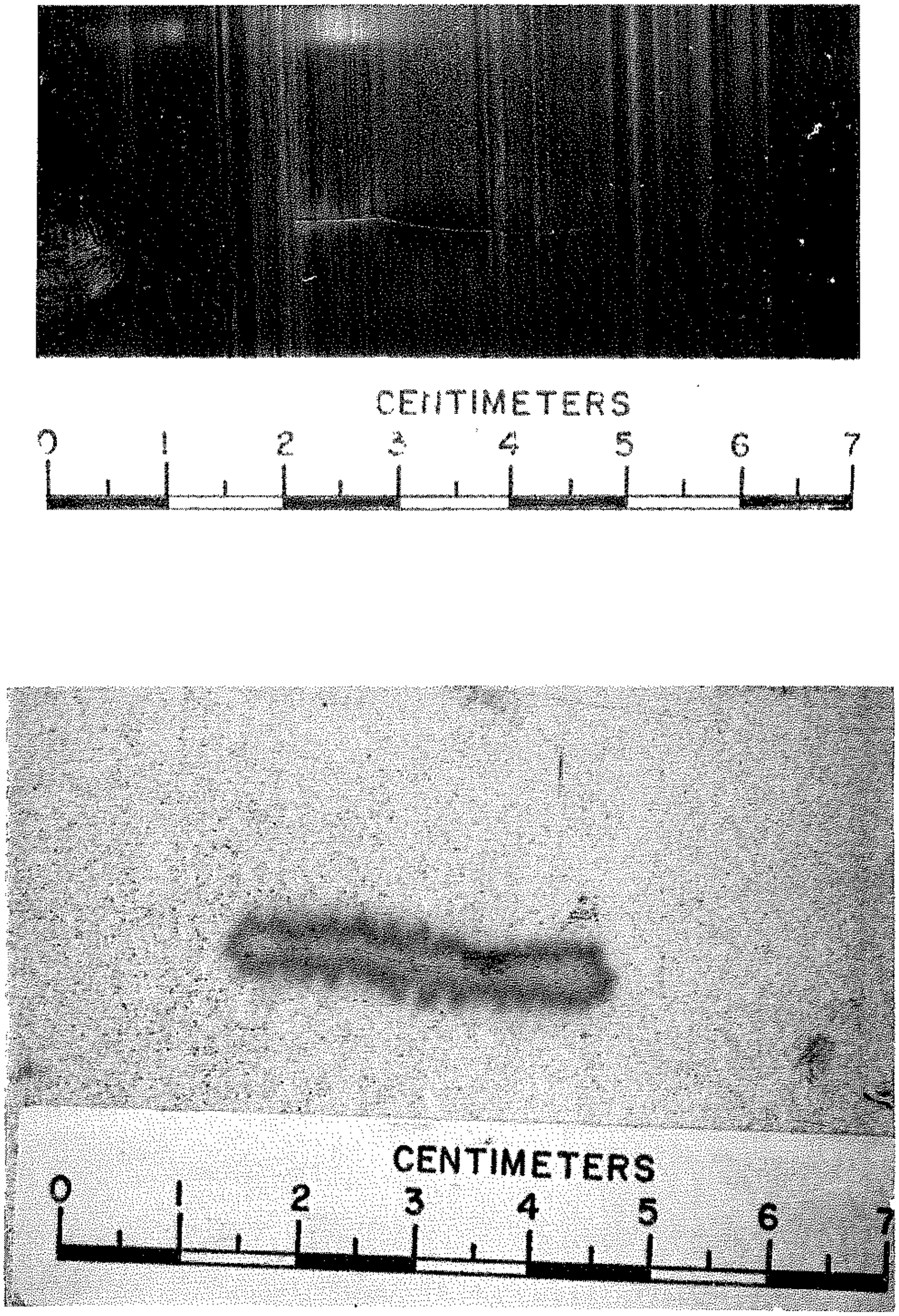


Figure 12 Photographs of crack 3 before and after application of dye penetrant.

**Table 1**

**TEST WHEEL SURFACE ROUGHNESS**

**Average Minimum & Maximum Surface Roughness Readings (Nanometres)**

| Brake Shoe | Before Brake Tests | | After Brake Tests | |
|---|---|---|---|---|
| | Along PtA | Along PtB | Along PtA | Along PtB |
| 3 JA | 180-360 | 200-380 | 230-480 | 230-460 |
| 2 JB | - | - | 250-500 | 250-530 |
| Wheel Surface Remachined and Polished | | | | |
| C13 | <250 | <250 | 180-300 | 180-280 |
| 1 JA | 180-250 | 180-250 | 200-360 | 200-380 |
| C14 | 180-300 | 180-330 | 200-380 | 200-360 |

**Table 2**

**SUMMARY OF TESTING**

| Test | Brake Shoe Code | Test Type | Speed km/h | Load Newtons | Water Spray mL/min | Avg. Coef. of friction | Note |
|---|---|---|---|---|---|---|---|
| 1-7 | C13 | Dry | 50 | 5800 | - | .376 | |
| 8-14 | C13 | " | 80 | " | - | .331 | |
| 15-21 | C13 | " | 50 | 8900 | - | .349 | |
| 22-28 | C13 | " | 80 | " | - | .325 | |
| 29-34 | C13 | Wet | 50 | 5800 | 400 | .035 | |
| 35-40 | C13 | " | 80 | " | 400 | .034 | |
| 41-46 | C13 | " | 50 | 8900 | 400 | .024 | |
| 47-52 | C13 | " | 80 | " | 400 | .026 | |
| 53-58 | 3JA | Wet | 50 | 5800 | 400 | .023 | |
| 59-64 | 3JA | " | 80 | " | 400 | .023 | |
| 65-70 | 3JA | " | 50 | 8900 | 400 | .018 | |
| 71-76 | 3JA | " | 80 | " | 400 | .020 | |
| 77-83 | 3JA | Dry | 50 | 5800 | - | .380 | |
| 84-90 | 3JA | " | 80 | " | - | .353 | |
| 91-97 | 3JA | " | 50 | 8900 | - | .391 | |
| 98-104 | 3JA | " | 80 | " | - | .338 | |
| 105-110 | 2JB | Wet | 50 | 5800 | 400 | .029 | |
| 111-116 | 2JB | " | 80 | " | 400 | .036 | |
| 117-122 | 2JB | " | 50 | 8900 | 400 | .024 | |
| 123-128 | 2JB | " | 80 | " | 400 | .025 | |
| 129-135 | 2JB | Dry | 50 | 5800 | - | .406 | |
| 136-142 | 2JB | " | 80 | " | - | .322 | |
| 143-149 | 2JB | " | 50 | 8900 | - | .429 | |
| 150-156 | 2JB | " | 80 | " | - | .323 | Note 1 |

Note 1: At conclusion of Test 156, 8 cracks were found on wheel surface. The wheel was removed from the test rig and was machined to remove the cracks.

**Table 2 (Cont'd)**

**SUMMARY OF TESTING**

| Test | Brake Shoe Code | Test Type | Speed km/h | Load Newtons | Water Spray mL/min | Avg. Coef. of friction | Note |
|---|---|---|---|---|---|---|---|
| | Note 2: | C13 Shoe | Retested | to Verify | Procedure | | Note 2 |
| 157-163 | C13 | Dry | 50 | 5800 | - | .375 | |
| 164-170 | C13 | " | 80 | " | - | .319 | |
| 171-177 | C13 | " | 50 | 8900 | - | .336 | |
| 178-184 | C13 | " | 80 | " | - | .271 | |
| 185-190 | C13 | Wet | 50 | 5800 | 400 | .030 | |
| 191-196 | C13 | " | 80 | " | 400 | .020 | |
| 197-202 | C13 | " | 50 | 8900 | 400 | .016 | |
| 203-208 | C13 | " | 80 | " | 400 | .016 | |
| 209-214 | 1JA | Wet | 50 | 5800 | 400 | .020 | |
| 215-220 | 1JA | " | 80 | " | 400 | .019 | |
| 221-226 | 1JA | " | 50 | 8900 | 400 | .018 | |
| 227-232 | 1JA | " | 80 | " | 400 | .017 | |
| 233-235 | 1JA | " | 50 | 5800 | 400 | .016 | to Check earlier Tests |
| 236-242 | 1JA | Dry | 50 | " | - | .438 | |
| 243-249 | 1JA | " | 80 | " | " | .356 | |
| 250-251 | 1JA | " | 50 | 8900 | - | Note 3 | No Valid Results |
| 253-255 | 1JA | " | 80 | " | - | Note 3 | " |
| 256-261 | C14 | Wet | 50 | 5800 | 400 | .021 | |
| 262-267 | C14 | " | 80 | " | 400 | .022 | |
| 268-273 | C14 | " | 50 | 8900 | 400 | .022 | |
| 274-279 | C14 | " | 80 | " | 400 | .020 | |
| 280-286 | C14 | Dry | 50 | 5800 | - | .413 | |
| 287-293 | C14 | " | 80 | " | - | .350 | |
| 294-296 | C14 | " | 50 | 8900 | - | Note 3 | No Valid Results |
| 297-299 | C14 | " | 80 | " | - | Note 3 | " |

Note 3: Problem traced to drive belt slippage; belt was tightened and verification tests No. 300 to 317 were made with C13 shoe.

**Table 2 (Cont'd)**

**SUMMARY OF TESTING**

| Test | Brake Shoe Code | Test Type | Speed km/h | Load Newtons | Water Spray mL/min | Avg. Coef. of friction | Note |
|---|---|---|---|---|---|---|---|
| 300-302 | C13 | Dry | 50 | 5800 | - | .334 | Belt Tension Adjusted |
| 303-305 | C13 | " | 80 | " | - | .324 | |
| 306-308 | C13 | " | 50 | 8900 | - | .331 | |
| 309-311 | C13 | " | 80 | " | - | .330 | |
| 312-314 | C13 | " | 50 | 5800 | - | .350 | |
| 315-317 | C13 | " | 80 | " | - | .327 | |
| Note 4: | End of Verification Tests | | | | | | Note 4 |
| Note 5: | Start Retest of C14 Shoe - Dry Tests Only | | | | | | Note 5 |
| 318-324 | C14 | Dry | 50 | 5800 | - | .343 | |
| 325-331 | C14 | " | 80 | " | - | .336 | |
| 332-338 | C14 | " | 50 | 8900 | - | .340 | |
| 339-345 | C14 | " | 80 | " | - | .298 | |
| Note 6: | Tests to Verify Method and Equipment after Long Shutdown | | | | | | |
| 346-348 | C13 | Dry | 50 | 5800 | - | .328 | Note 6 |
| 349-351 | C13 | Wet | 50 | 5800 | 400 | .035 | |
| Note 7: | Retest of 1JA Shoe | | | | | | Note 7 |
| 352-357 | 1JA | Wet | 50 | 5800 | 400 | .018 | |
| 358-363 | 1JA | " | 80 | " | 400 | .017 | |
| 364-369 | 1JA | " | 50 | 8900 | 400 | .013 | |
| 370-375 | 1JA | " | 80 | " | 400 | .011 | |
| 376-382 | 1JA | Dry | 50 | 5800 | - | .440 | |
| 383-389 | 1JA | " | 80 | " | - | .348 | |
| 390-392 | 1JA | " | 50 | 8900 | - | .386 | Note 8 |
| Note 8: | Limited Tests to Avoid Damage to Control Unit | | | | | | |
| 393-399 | 1JA | Dry | 80 | 8900 | - | .332 | |

**Table 2 (Cont'd)**

**SUMMARY OF TESTING**

| Test | Brake Shoe Code | Test Type | Speed km/h | Load Newtons | Water Spray mL/min | Avg. Coef. of friction | Note |
|---|---|---|---|---|---|---|---|
| 400-405 | 4JA | Wet | 50 | 5800 | 400 | .024 | |
| 406-411 | 4JA | " | 80 | " | 400 | .024 | |
| 412-417 | 4JA | " | 50 | 8900 | 400 | .017 | |
| 418-423 | 4JA | " | 80 | " | 400 | .020 | |
| 424-430 | 4JA | Dry | 50 | 5800 | - | .395 | |
| 431-437 | 4JA | " | 80 | " | - | .309 | |
| 438-444 | 4JA | " | 50 | 8900 | - | .348 | |
| 445-451 | 4JA | " | 80 | " | - | .309 | |
| Note 9: Start Final Tests with C13 Reference Shoe | | | | | | | Note 9 |
| 452-457 | C13 | Wet | 50 | 5800 | 400 | .036 | |
| 458-463 | C13 | " | 80 | " | 400 | .031 | |
| 464-469 | C13 | " | 50 | 8900 | 400 | .021 | |
| 470-475 | C13 | " | 80 | " | 400 | .019 | |
| 476-482 | C13 | Dry | 50 | 5800 | - | .381 | |
| 483-489 | C13 | " | 80 | " | - | .313 | |
| 490-496 | C13 | " | 50 | 8900 | - | .350 | |
| 497-503 | C13 | " | 80 | " | - | .311 | |

End of Series.

Note: 5800 Newtons = 1300 pounds
8900 Newtons = 2000 pounds

**Table 3**

**C13 Cobra Standard Reference Shoe Tests**

A. Summary of Dry Friction Coefficients

| Test | Time Period | Brake Shoe Load Newtons | Coefficients @ 50 km/h | Coefficients @ 80 km/h |
|---|---|---|---|---|
| 1-14 | Nov. 84 | 5800 | .38 | .33 |
| 157-163 | Apr. 85 | " | .38 | .32 |
| 312-317 | May 85 | " | .35 | .33 |
| 476-489 | Oct. 85 | " | .38 | .31 |
| 15-28 | Nov. 84 | 8900 | .35 | .33 |
| 171-184 | Apr. 85 | " | .34 | .27 |
| 306-311 | May 85 | " | .35 | .33 |
| 490-503 | Oct. 85 | " | .35 | .31 |

B. Summary of Wet Friction Coefficients

| Test | Time Period | Brake Shoe Load Newtons | Coefficients @ 50 km/h | Coefficients @ 80 km/h |
|---|---|---|---|---|
| 29-40 | Nov. 84 | 5800 | .04 | .03 |
| 185-196 | Apr. 85 | " | .03 | .02 |
| 452-463 | Oct. 85 | " | .04 | .03 |
| 41-52 | Nov. 84 | 8900 | .02 | .03 |
| 197-208 | Apr. 85 | " | .02 | .02 |
| 464-475 | Oct. 85 | " | .02 | .02 |

Note: 5800 Newtons = 1300 pounds
8900 Newtons = 2000 pounds

**Table 4**

**Summary of Dry Friction Tests**

| Brake Shoe Load Newtons | Brake Shoe Code Number | Friction Coefficient @ 50 km/h | Friction Coefficient @ 80 km/h |
|---|---|---|---|
| 5800 | 1JA | .44 | .35 |
| 5800 | 2JB | .41 | .32 |
| 5800 | 3JA | .38 | .35 |
| 5800 | 4JA | .40 | .31 |
| 5800 | C13 Avg. | .37 | .31 |
| 5800 | C14 | .34 | .34 |
| 8900 | 1JA | .39 | .33 |
| 8900 | 2JB | .43 | .32 |
| 8900 | 3JA | .39 | .34 |
| 8900 | 4JA | .35 | .31 |
| 8900 | C13 Avg. | .35 | .31 |
| 8900 | C14 | .34 | .30 |

Note: 5800 Newtons = 1300 pounds
8900 Newtons = 2000 pounds

**Table 5**

**Summary of Wet Friction Tests**

| Brake Shoe Load Newtons | Brake Shoe Code Number | Friction Coefficient | |
|---|---|---|---|
| | | @ 50 km/h | @ 80 km/h |
| 5800 | 1JA | .02 | .02 |
| 5800 | 2JB | .03 | .04 |
| 5800 | 3JA | .02 | .02 |
| 5800 | 4JA | .02 | .02 |
| 5800 | C13 Avg. | .04 | .03 |
| 5800 | C14 | .02 | .02 |
| 8900 | 1JA | .01 | .01 |
| 8900 | 2JB | .02 | .03 |
| 8900 | 3JA | .02 | .02 |
| 8900 | 4JA | .02 | .02 |
| 8900 | C13 Avg. | .02 | .02 |
| 8900 | C14 | .02 | .02 |

Note: 5800 Newtons = 1300 pounds
8900 Newtons = 2000 pounds

**Table 6**

**Comparison with Previous Cobra Shoe Tests**

A. Summary of Dry Friction Tests

| Brake Shoe Load Newtons | Brake Shoe Code Number | Friction Coefficient @ 50 km/h | @ 80 km/h |
|---|---|---|---|
| 5800 | C1 - Note 1 | .33 | .31 |
| 5800 | C2 - " 1 | .34 | .31 |
| 5800 | C3 - " 1 | .33 | - |
| 5800 | C4 - " 1 | .35 | .32 |
| 5800 | C13 - " 2 | .38 | .34 |
| 5800 | C13 Avg. | .37 | .34 |
| 5800 | C14 | .34 | .34 |
| 8900 | C1 - Note 1 | .30 | .30 |
| 8900 | C2 - " 1 | .34 | .31 |
| 8900 | C3 - " 1 | .32 | .31 |
| 8900 | C4 - " 1 | .33 | .30 |
| 8900 | C13 - " 2 | .35 | .34 |
| 8900 | C13 Avg. | .35 | .31 |
| 8900 | C14 | .34 | .30 |

B. Summary of Wet Friction Tests

| Brake Shoe Load Newtons | Brake Shoe Code Number | Friction Coefficient @ 50 km/h | @ 80 km/h |
|---|---|---|---|
| 5800 | C2 - Note 1 | .05 | .04 |
| 5800 | C4 - " 1 | .03 | .03 |
| 5800 | C13 - " 2 | .03 | .03 |
| 5800 | C13 Avg. | .04 | .03 |
| 5800 | C14 | .02 | .02 |
| 8900 | C2 - Note 1 | .03 | .02 |
| 8900 | C4 - " 1 | .02 | .02 |
| 8900 | C13 - " 2 | .02 | .02 |
| 8900 | C13 Avg. | .02 | .02 |
| 8900 | C14 | .02 | .02 |

Note 1 - (Ringer, 1983)
Note 2 - (Allard, 1984)

# APPENDIX A

## EQUIPMENT

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