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TRACTION MOTOR SUSPENSION BEARING LEAKAGE TESTS PHASE IV MIGRATION OF WATER VAPOUR INTO BEARING RESERVOIRS

SUBMITTED BY / PRÉSENTÉ PAR: T. R. Ringer, LABORATORY HEAD / CHEF DE LABORATOIRE

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SUMMARY

Canadian railways have experienced a greater rate of failure of locomotive traction motor suspension bearings during winter operation than at other times of the year. A suspected cause of the increased failure rate was the presence of water in the lubricating oil reservoirs of the bearings. One method by which water may enter the reservoirs is in the form of water vapour. A traction motor gear case was fitted with a water filled electrically heated sump and the water vapour hypothesis verified. It was shown that the presence of heat in either the motor field windings or the gear case sump was sufficient to create water vapour in the gear case which would migrate to the bearing oil reservoirs and be condensed. Blockage of either the gear case overflow vent or the gear case seal drain increased the amount of water being carried over to the reservoirs. Pressurizing the gear case to 100 pascals (0.4" H_2O) with air was sufficient to reduce the amount of water entering the gear case through the seals under rain conditions by a factor of 10. Further study of the effects of pressurizing the gear case or the suspension bearing oil reservoirs is indicated.

1.0 INTRODUCTION

Canadian railways have, for some time, been experiencing an abnormal number of failures of locomotive traction motor suspension bearings during winter operation and with the introduction of higher powered locomotives the winter failure rate is increasing. A contributing factor to the increased failure rate is believed to be the presence of water (and dirt carried with the water) in the bearing oil reservoirs. The source of the water is snow which is picked up from the roadbed by train drag, deposited on the traction motor and then melted by heat from the motor frame and gear case. The Low Temperature Laboratory of the National Research Council has been asked by the Canadian railways to investigate the means by which the water enters the suspension bearing reservoirs and, if possible, devise a solution to the problem.

Three mechanisms by which the water may enter the bearing reservoirs have been postulated. First the water may enter by direct leakage through the various joints between the motor frame, bearing cap and bearing shells. Secondly, it may enter by being hydraulically forced through the bearing clearance spaces by the opening and closing of the space at the thrust bearing faces by the lateral motion of the axle set as the locomotive moves down the track. Thirdly, the water may enter as a vapour after having been vapourized on the warm parts of the motor and in the gear case and subsequently condensed by the cool walls of the bearing oil reservoir.

As reported previously(1)(2), it has been established that water can enter the support bearing oil reservoirs by direct leakage through any small clearance spaces around shims or small capillary grooves in the cap and frame joints. They have further established that if water enters the space between the bearing thrust faces it can be forced hydraulically into the bearing oil reservoirs by lateral movement of the wheel set. During the course of the investigations it was noted that large amounts of water (up to 500 ml/6-hour test) could enter the gear case through its various seals. Energy losses in the gear train of a locomotive in normal operations are sufficient to evaporate the water entering the gear case and it is possible that the resulting vapour could migrate from the gear case to the support bearing reservoirs.

This report outlines the results of tests designed to determine if water vapour generated in the gear case could migrate to the support bearing reservoirs and condense there. Various vents and drains on the gear case were blocked to simulate the effects of conditions that might arise in the field.

2.0 TEST APPARATUS

The water vapour migration tests were carried out on the locomotive traction motor suspension bearing test facility which consists of a complete traction motor and wheel set mounted in a large suspension frame. The wheel set is equipped with a DC electric motor drive. Provision has been made to move the traction motor laterally and to apply heat to the traction motor field windings to simulate locomotive running conditions. The equipment can be subjected to either driving rain or snow. Full details of the test facility have been given in a previous report(1).

Modifications to the traction motor for the water vapour migration tests consisted of adding a small sump to the bottom of a steel gear case and installing a 3 kW electric heater in the sump. Water was supplied to the sump from a small reservoir where the water level was controlled by a float. The power supply to the electric heater was controlled by a 220-volt rheostat. Fibreglass insulation was installed around the sump to prevent unnecessary heat loss from it to the surrounding atmosphere. The modified gear case without insulation is shown in Fig. 1 and the reservoir with float control is shown in Fig. 2.

The suspension bearings were fitted with standard wick oilers with clear plexiglass covers (see Fig. 3).

The traction motor used in the test had the following nameplate data:-

Diesel Division, General Motors of
Canada Limited, London, Can.
Model No. - D77B
Serial No. - 72M1024

3.0 TEST PROCEDURE

The steel gear case with integral sump was assembled on the traction motor and connected to the water supply reservoir. The water level in the reservoir was adjusted to maintain a constant level in the gear case which was above the immersion heater but below the main drive gear on the axle set. The gear case was fitted with standard felt seals running on the wheel hub and gear hub. A double lip modified urethane seal was installed on the thrust flange of the pinion end suspension bearing and a closed cell neoprene foam seal was installed on the motor shaft hub. The remaining gear case seals were standard felt seals.

The procedure for carrying out a test run consisted of rotating the wheel set at 24 km/h, establishing the desired test conditions, and then subjecting the traction motor to six hours of driving rain. On the morning following the test, any accumulated water in the suspension bearing reservoirs was drained and measured.

The conditions tested during this series of tests were:

1. Normal condition of bearing seals - tests 174, 175, 184, 185, 192, 193.
2. Effect of applying heat to motor field winding only - tests 176, 183.
3. Effect of applying heat to the motor field winding and to the gear case sump - tests 177, 178, 179.
4. Effect of low ambient temperature (+3°C) on the migration of water vapour from the gear case sump with heat on the motor field winding and the gear case sump - tests 180, 181.

5. Effect of low ambient temperature (+3^{o}C) on the migration of water vapour with heat applied to the motor field winding only - test 182.

6. Effect of blocking the gear case vent on the migration of water vapour with heat applied to the motor field winding and the gear case sump - tests 186, 187.

7. Effect of blocking both the gear case vent and the seal drain on the migration of water vapour with heat applied to the motor field winding and the gear case sump - tests 188, 189.

8. Effect of blocking the seal drain only (gear case vent open) on the migration of water vapour with heat applied to the motor field winding and the gear case sump - tests 190, 191.

9. Effect of pressurizing the gear case with compressed air at 100 pascals (0.4" H_2O) on the amount of water entering the gear case - tests 194, 195, 196.

4.0 OBSERVATIONS

A summary of the test conditions and measured leakage rates for each test run is given in Table I. Full details of test conditions and observations are given in Appendix A.

Six test runs (174, 175, 184, 185, 192, 193) were carried out during this phase to check the integrity of the mechanical sealing of the suspension bearing oil reservoirs and gear case. The leakage rates during these tests are as follows:

Test No.	Leakage rate, ml/6-hour test		
	Commutator end reservoir	Pinion end reservoir	Gear case
174	0.2	<0.1	50
175	0.2	0.1	30
184	<0.1	0.4	-
185	0.1	0.2	-
192	0.2	2.5	44
193	0.4	0.6	27

Leakage into the commutator end oil reservoir was essentially unchanged during the test series indicating that the bearing sealing was intact. There was a slight increase of leakage into the pinion end oil reservoir during tests 192 and 193. It is believed that this increase of leakage is due to carry-over of moisture from the previous test rather than any failure of the sealing. On subsequent tests (195, 196) the leakage into the pinion end bearing reservoir was

0.1 ml, the same as in the beginning (test 174). Leakage through the rotating seals into the gear case remained constant at 30-50 ml per 6-hour test. No deterioration of the oil reservoir seal was noted during the test program. It can be assumed that any increase in water found in the bearing oil reservoirs was due to the migration of water vapour to the reservoirs.

Tests 176 and 183 measured the effect of applying heat to the stator frame on the amount of water accumulating in the bearing reservoirs. Leakage rates were measured as follows:

Test No.	Leakage rate, ml/6-hour test	
	Commutator end reservoir	Pinion end reservoir
176	0.3	0.1
183	0.1	0.9

After test 176 the oil in the commutator end reservoir had a hazy appearance and was full of very fine droplets. The larger water droplets were not clear water but seemed to be an emulsion. The pinion end reservoirs had some small droplets of water in the oil but the oil retained its clear colour. Condensation was noted on the inside surface of the reservoir window after both tests. It is apparent that the application of heat to the stator winding is sufficient to move water vapour into the bearing oil reservoirs.

Three tests (177, 178 and 179) were conducted to determine the effect of applying heat to both the stator field winding and to the water in the gear case sump on the amount of water vapour entering the bearing oil reservoirs. The amount of water entering the bearings during each test was as follows:

Test No.	Leakage rate, ml/6-hour test	
	Commutator end reservoir	Pinion end reservoir
177	0	2
178	0.1	3.9
179	0.3	2.5

The amount of water entering the pinion end reservoir had increased from the approximately 0.2 ml without heat to approximately 2.5 ml per test with heat. Condensation was present on the clear windows of both bearing reservoirs following each test. The commutator end oil had a hazy appearance and contained very fine droplets on completion of each test. The pinion end oil also contained many small droplets (larger than at the commutator end) after each test. Figure 4 shows a view of the condensate on the window of the commutator end oil reservoir and Figure 5 shows the condensate on the pinion end oil reservoir window. These three tests show that if water entered the gear case of a working locomotive and was evaporated by heat from the gear train, some of the vapour would migrate to the pinion end bearing reservoir and be condensed.

The effect of low ambient temperatures (+3°C) on the migration of water vapour into the oil reservoirs was evaluated during tests 180 and 181. During these two tests heat was applied to the stator field windings and to the gear case sump. Measured leakage rates were as follows:

Test No.	Leakage rate, ml/6-hour test	
	Commutator end reservoir	Pinion end reservoir
180	0.1	1.9
181	0.1	1.5

Condensation was present on both reservoir windows on completion of the test runs. Small water droplets were present in the oil.

Vapour migration to the pinion end reservoir was somewhat less at low ambient temperature than it was at room temperature but was considerably more than it was with the reference tests (174-193) when no heat was applied to the stator field winding and the gear case sump.

A single test (182) was carried out at low ambient temperature (+3°C) with heat applied to the stator field winding only (no heat on gear case). Leakage rates were as follows:

Test No.	Leakage rate, ml/6-hour test	
	Commutator end reservoir	Pinion end reservoir
182	<0.1 ml	0.9 ml

Water was present in the gear case sump during this run. Leakage into the pinion end reservoir was less without heat on the gear case than it was with heat on the gear case but is more than the reference tests (174-193) when no heat is applied to the field windings. Condensation was present on both reservoir windows at the end of the test. The oil in the reservoir was clear with some droplets of water present.

A series of six tests (186-191) was carried out to determine the effect on vapour migration of a blockage in either the gear case overflow vent and/or the gear case seal drain. Heat was applied to both the stator field windings and the gear case sump. Measured leakage rates were as follows:

Test No.	Conditions	Leakage rate, ml/6-hour test	
		Commutator end reservoir	Pinion end reservoir
186	Overflow vent blocked and	0.3	2.7
187	Seal drain open	0.1	4.7
188	Overflow vent and	0.3	5.9
189	Seal drain blocked	0.2	7.3
190	Seal drain blocked and	0.4	2.7
191	Overflow vent open	0.1	5.3

On completion of each test condensation was present on the oil reservoir windows and water droplets were present in the oil. It is apparent that blockage of either the overflow vent or the seal drain causes an increase in the amount of water vapour migrating to the pinion end oil reservoir. A slight increase in condensation in the commutator end oil reservoir was also noted.

It was apparent from the tests that if water and heat were present in the gear case, the resulting water vapour would be carried over into the suspension bearing reservoirs. If any of the vents or drains were blocked the amount of water vapour carried over was increased. This situation could be prevented if water would be prevented from entering the gear case. The felt seals currently used on the gear case do not prevent water from entering the gear case (Ref. 2). One alternative solution was to pressurize the gear case with low pressure (100 pascals or 0.4" H_2O) air. Two tests (195, 196) were carried out with the gear case pressurized but without heat on either the gear case sump or the motor field windings. Leakage into the gear case and bearing oil reservoirs was as follows:

Test No.	Leakage rate, ml/6-hour test		
	Commutator end reservoir	Pinion end reservoir	Gear case
195	0.1	<0.1	2.5
196	0.1	0.1	0.5

On previous tests (174, 175, 192, 193) leakage into the gear case had been between 27 and 50 ml per 6-hour test. Pressurizing the gear case had reduced the leakage into the gear case by a factor of 10.

5.0 CONCLUSIONS

1. In all cases where heat was supplied by either the motor field winding or by both the field winding and the gear case sump heating element, water vapour was transferred to the pinion end oil reservoir. The quantity of vapour transferred increased when the gear case overflow vent and/or the gear case seal drain was blocked. Water vapour was also induced into the commutator end oil

reservoir, as indicated by condensation on the reservoir window when heat was supplied by the stator field winding and the gear case heating element. The measured amount of water removed from the commutator end reservoir was only slightly greater than it was when no heat was applied.

2. A decrease in the ambient temperature (from room to +3°C) appears to reduce the amount of water vapour induced into the oil reservoirs (from 2.6 ml avg. to 1.7 ml avg. at the pinion end).

3. An essential ingredient to the generation and movement of water vapour is the presence of heat generated either in the motor field windings or in the gear case.

4. It has been shown that water vapour migrates from the gear case to the oil reservoirs when either or both the gear case overflow and the seal drain were open. The provision of additional vents or drains in the gear case is not a solution.

5. Pressurizing the gear case with low pressure air (100 pascals or 0.4" H_2O) reduced the amount of water entering the gear case dramatically (30-50 ml to 0.5-2.5). Eliminating water from the gear case by this method may be an effective solution to the generation of water vapour in the gear case and its subsequent migration to the suspension bearing oil reservoirs. Pressurization of the oil bearing reservoirs may also be effective in preventing both water vapour and liquid water from entering. It is recommended that further investigations of the effects of pressurizing the oil reservoirs be carried out.

6.0 REFERENCES

1. J. F. Lane, D. E. Morris — Traction Motor Suspension Bearing Leakage Tests. Phases I and II. NRC Report LTR-LT-100, July 1979.

2. J. F. Lane, D. E. Morris — Traction Motor Suspension Bearing Leakage Tests. Phase III. NRC Report LTR-LT-106, October 1979.

TABLE I LOCOMOTIVE TRACTION MOTOR SUSPENSION BEARINGS

SUMMARY OF TEST RESULTS - PHASE IV

Date 1979	Test Run No.	Speed km/h	Shaker Hz	Rain ℓ/sec.	Wind Speed km/h	Test Duration h	Stator Heat kVA	Gear Case Heat kW	Water Leakage Comm. End ml	Water Leakage Pinion End ml	Water Leakage Gear Case ml	Comments
		Steel gear case installed with water reservoir and 3 kW electric heater to generate vapour in gear case. Gear case fitted with felt seals on wheel and gear hubs, modified urethane double lip seal on thrust flange and neoprene foam rubber seal on motor shaft hub. Standard rubber boot over commutator end thrust faces.										
31 July	174	24	0.5	0.057	32	6	0	0	0.2	<0.1	50	Test run
1 Aug	175	24	0.5	0.057	32	6	0	0	0.2	0.1	30	Repeat of 174
2 Aug	176	24	0.5	0.057	32	6	10	0	0.3	0.1	8	
		Pinion end oil - clear; commutator end oil - hazy, full of small droplets.										
15 Aug	177	24	0.5	0.057	32	6	10	3	0	2	-	
		Pinion end oil - some fine droplets; commutator end oil - milky, very fine droplets in suspension.										
16 Aug	178	24	0.5	0.057	32	6	10	3	0.1	3.9	-	Repeat of 177
		Pinion end oil - some droplets; commutator end oil - droplets in suspension not as fine as Run 177.										
17 Aug	179	24	0.5	0.057	32	6	10	3	0.3	2.5	-	Repeat of 177
		Pinion end oil - small drops water; commutator end oil - many water droplets; condensation on both windows.										

TABLE I (cont'd) LOCOMOTIVE TRACTION MOTOR SUSPENSION BEARINGS

SUMMARY OF TEST RESULTS - PHASE IV

Date 1979	Test Run No.	Speed km/h	Shaker Hz	Rain ℓ/sec.	Wind Speed km/h	Test Duration h	Stator Heat kVA	Gear Case Heat kw	Water Leakage Comm. End ml	Water Leakage Pinion End ml	Water Leakage Gear Case ml	Comments
20 Aug	180	24	0.5	0.057	32	6	10	3	0.1	1.9	-	Ambient +3°C
		Condensation on 75% pinion window, 10% of commutator end window. Oil in both bearings clear with some droplets in suspension.										
21 Aug	181	24	0.5	0.057	32	6	10	3	0.1	1.5	-	Repeat of 180
		Condensation on 60% pinion window, 15% of commutator end window. Oil in both bearings clear with some droplets in suspension.										
22 Aug	182	24	0.5	0.057	32	6	10		<0.1	0.9	-	Ambient +3°C
		Condensation on 20% pinion window, 15% of commutator end window. Oil clear in both bearings.										
23 Aug	183	24	0.5	0.057	32	6	10	0	0.1	0.9	-	Ambient 22°C
		Condensation on 20% pinion window, 50% of commutator end window at 8:00 AM. 24 Aug. oil clear in both bearings.										
24 Aug	184	24	0.5	0.057	32	6	0	0	<0.1	0.4	-	Test of seals
		Condensation on 5% pinion window, 25% of commutator end window. Oil clear in both bearings.										
27 Aug	185	24	0.5	0.057	32	6	0	0	0.1	0.2	-	Repeat of 184
		No condensation, oil clear, bearing oil reservoir seals good.										

TABLE I (cont'd) LOCOMOTIVE TRACTION MOTOR SUSPENSION BEARINGS

SUMMARY OF TEST RESULTS - PHASE IV

Date 1979	Test Run No.	Speed km/h	Shaker Hz	Rain ℓ/sec.	Wind Speed km/h	Test Duration h	Stator Heat kVA	Gear Case Heat kw	Water Leakage			Comments
									Comm. End ml	Pinion End ml	Gear Case ml	
28 Aug	186	24	0.5	0.057	32	6	10	3	0.3	2.7	-	Gear case vent plugged
		Condensation on 80% pinion end window, 40% commutator end window. Some water droplets in oil; oil clear.										
29 Aug	187	24	0.5	0.057	32	6	10	3	0.1	4.7	-	Repeat of 186
		Condensation on 80% pinion window, 40% commutator end window. Oil clear both bearings.										
30 Aug	188	24	0.5	0.057	32	6	10	3	0.3	5.9	-	Gear case vent and drain plugged
		Condensation on 80% pinion window, 40% commutator end window. Oil clear both bearings.										
31 Aug	189	24	0.5	0.057	32	6	10	3	0.2	7.3		Repeat of 188
		Condensation on 85% pinion window, 60% commutator end window. Oil clear both bearings.										
4 Sept	190	24	0.5	0.057	32	6	10	3	0.4	2.7		Gear case drain plugged, vent open
		Condensation on 80% pinion window, 50% commutator end window. Oil clear both bearings.										
5 Sept	191	24	0.5	0.057	32	6	10	3	0.1	5.3	-	Repeat of 190
		Condensation on 85% pinion window, 75% commutator end window. Oil clear both bearings.										

TABLE I (cont'd) LOCOMOTIVE TRACTION MOTOR SUSPENSION BEARINGS

SUMMARY OF TEST RESULTS - PHASE IV

Date 1979	Test Run No.	Speed km/h	Shaker Hz	Rain ℓ/sec.	Wind Speed km/h	Test Duration h	Stator Heat kVA	Gear Case Heat kW	Water Leakage Comm. End ml	Water Leakage Pinion End ml	Water Leakage Gear Case ml	Comments
6 Sept	192	24	0.5	0.057	32	6	0	0	0.2	2.5	44	Test of seals
		Condensation on 50% of both windows.										
10 Sept	193	24	0.5	0.057	32	6	0	0	0.4	0.6	27	Repeat of 192
		No condensation on windows; oil clear and free of droplets.										
11 Sept	194	24	0.5	0.057	32	6	10	3	--	--	--	Gear case pressurized to 100 pascals (0.4" H_2O)
		Gear case heater failed after 2.5 hours testing.										
12 Sept	195	24	0.5	0.057	32	6	0	0	0.1	<0.1	2.5 ml	Gear case pressurized to 100 pascals (0.4" H_2O)
13 Sept	196	24	0.5	0.057	32	6	0	0	0.1	0.1	0.5 ml	Repeat of 195

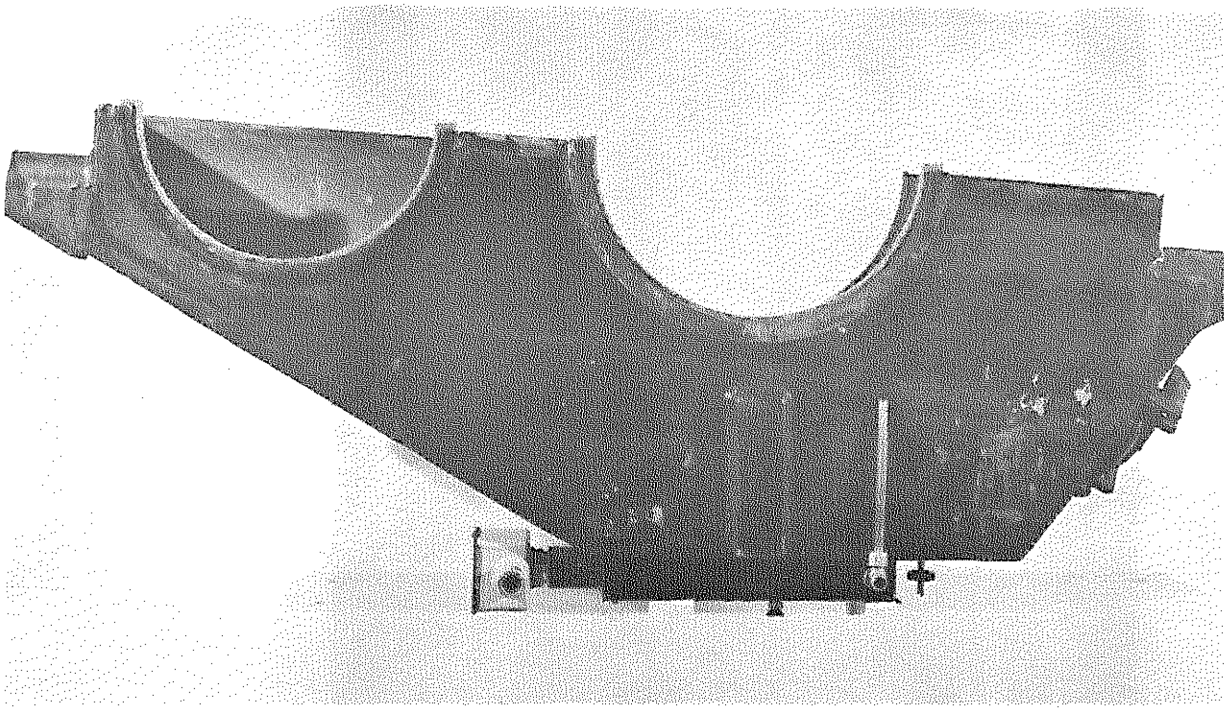

FIG. 1 STEEL GEAR CASE FITTED WITH WATER SUMP AND 3 kW ELECTRIC HEATER

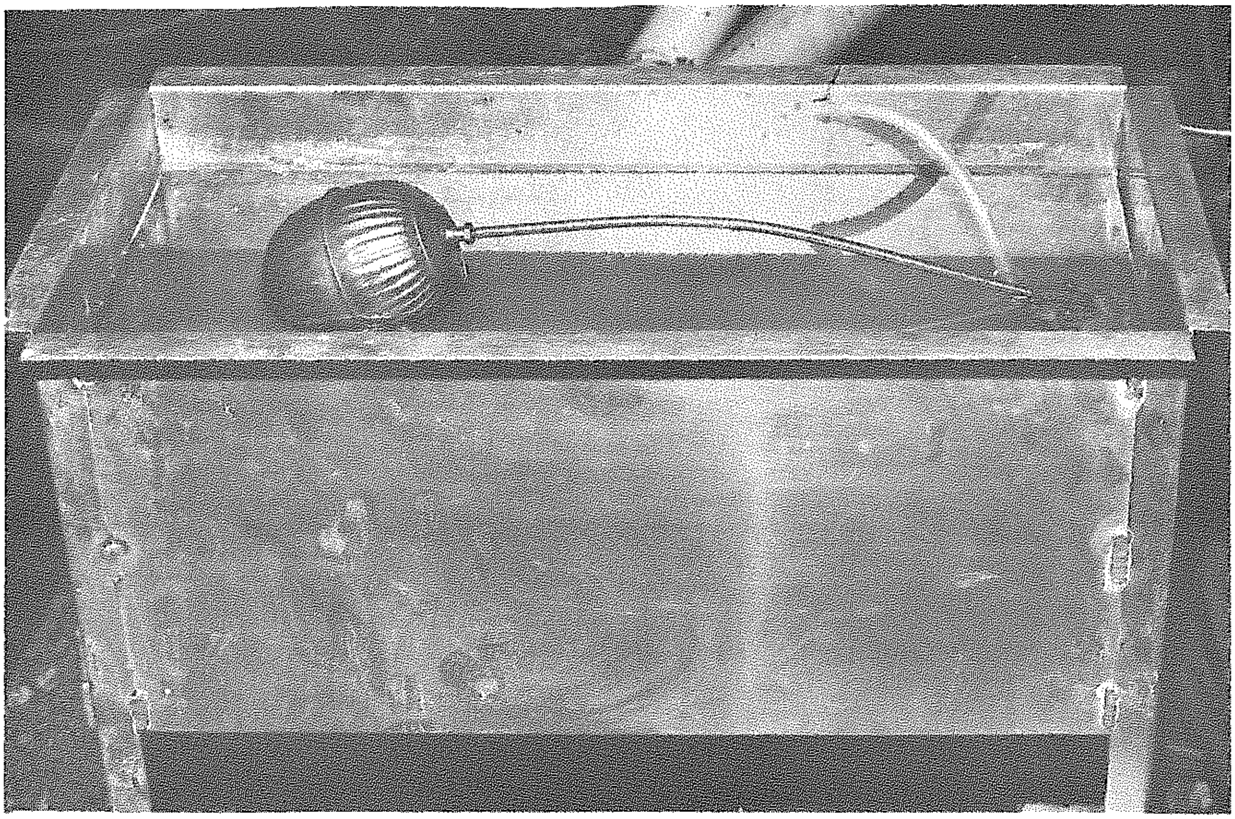

FIG. 2 WATER RESERVOIR WITH FLOAT LEVEL CONTROL

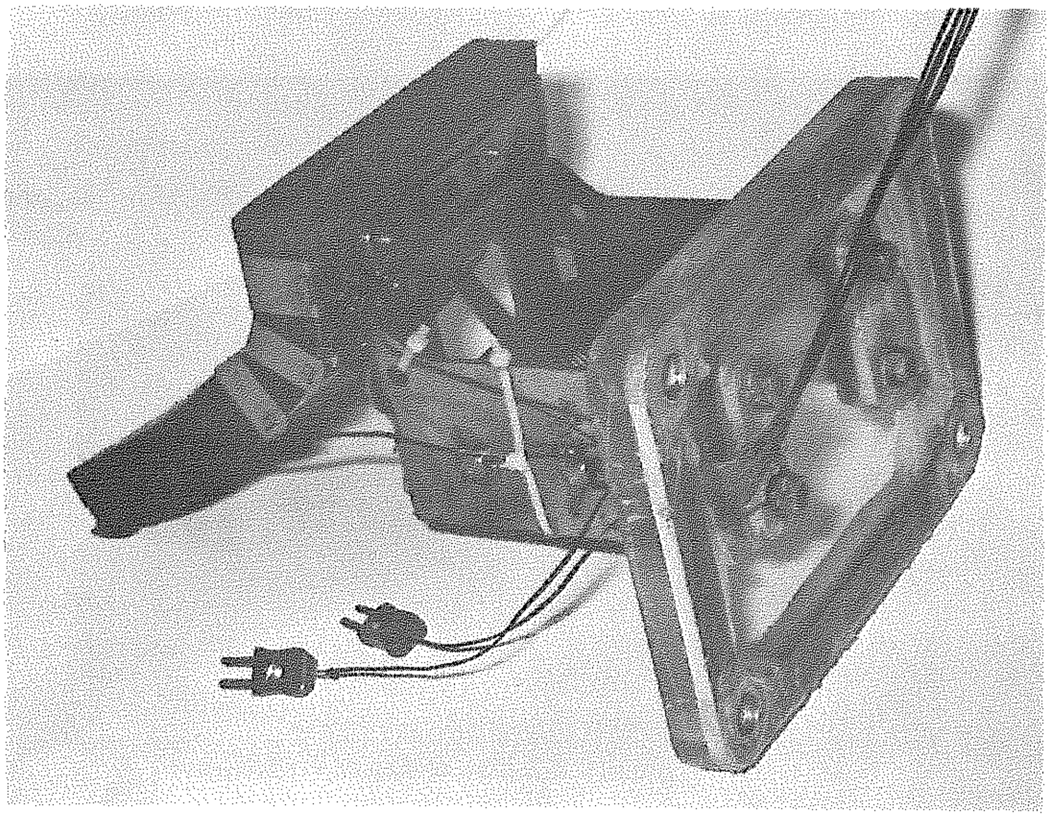

FIG. 3 WICK OILER WITH CLEAR PLEXIGLASS COVER

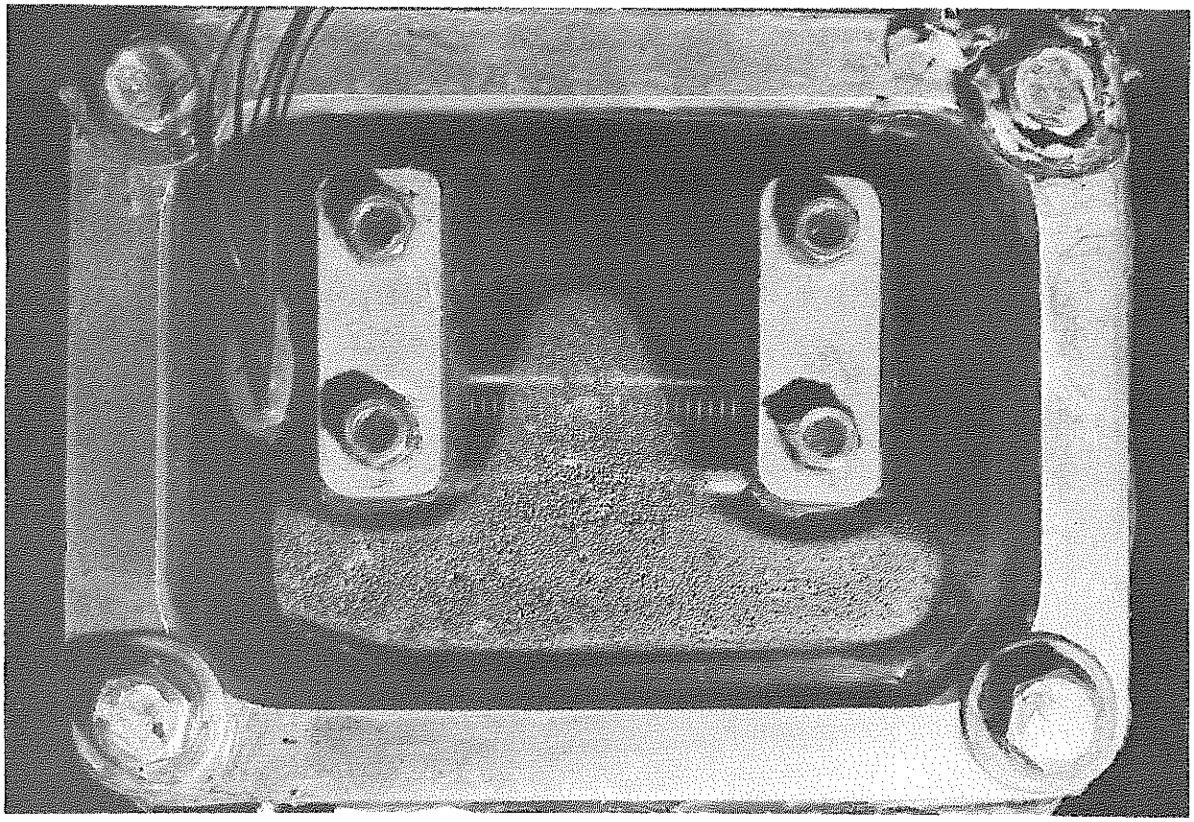

FIG. 4 CONDENSATE ON WINDOW OF COMMUTATOR END OIL RESERVOIR

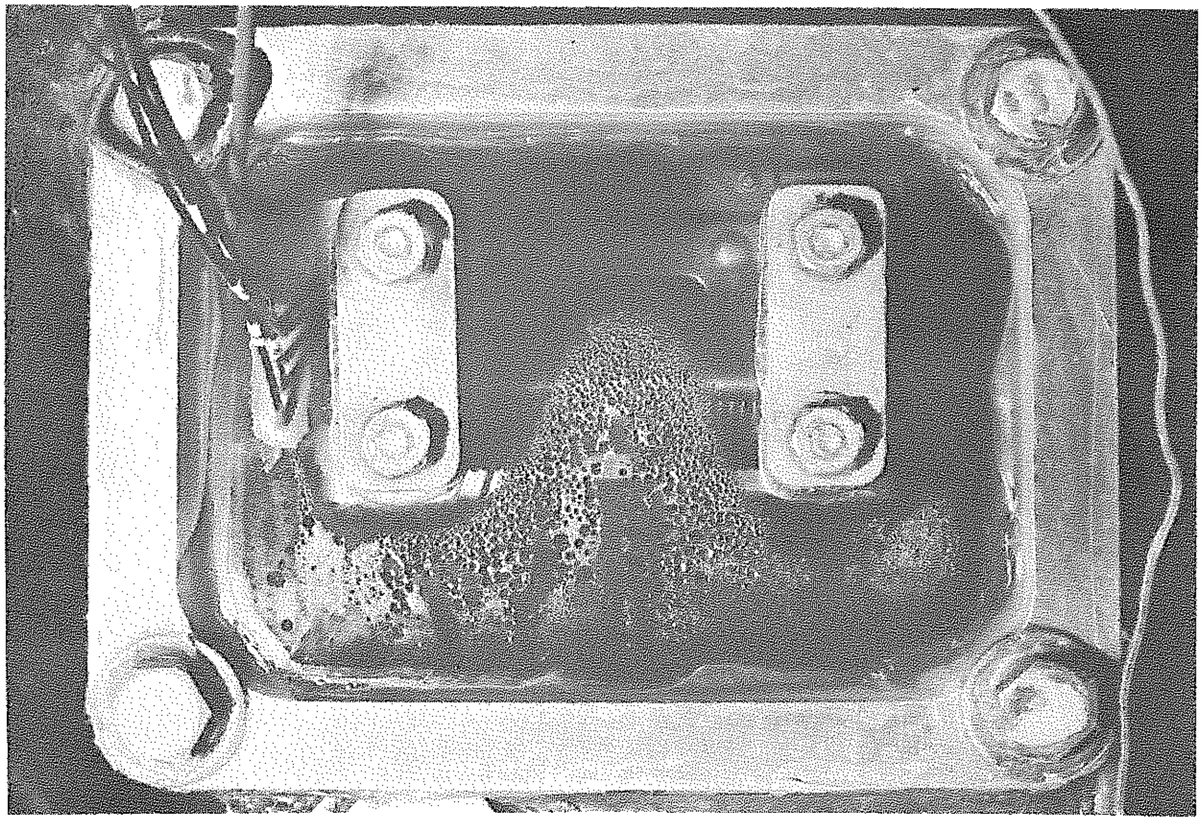

FIG. 5 CONDENSATE ON WINDOW OF
PINION END OIL RESERVOIR

APPENDIX A

LOCOMOTIVE TRACTION MOTOR SUSPENSION BEARINGS - PHASE IV - TESTS ON WATER VAPOUR MIGRATION BETWEEN 31 JULY 1979 AND 13 SEPTEMBER 1979 - GENERAL CONDITIONS

A G.M. Model D77B traction motor was installed in the NRC traction motor test rig. It was fitted with a steel gear case on which a water sump with a 3 kW electric heater had been installed. The water level in the gear case sump was controlled from a water reservoir with a float valve. The gear case was fitted with standard oiled felt seals on the wheel and gear hubs. A modified urethane double lip seal was installed on the suspension bearing pinion end thrust flange and a neoprene closed cell foam rubber seal of NRC manufacture was installed on the motor shaft hub. A standard rubber dust guard was installed over the commutator end bearing thrust faces. A rheostat was installed in the power supply to the 3 kW electric heater in the gear case sump to permit control of the heat going to the gear case. Standard wick oilers with clear plexiglass windows were installed in both oil reservoirs. All tests were of 6 hours duration.

Test Nos. 174, 175

Motor: as described above
Speed: 24 km/h
Shaker: 0.5 Hz
Wind: 32 km/h (2 fans on low)
Rain: 0.057 ℓ/sec.
Heat: Field winding - none
Gear case sump - none
Ambient temperature: 24°C
Duration: 6 hours

Test No.	Leakage rate, ml/6-hour test		
	Commutator end reservoir	Pinion end reservoir	Gear case
174	0.2	<0.1	50
175	0.2	0.1	30

Test No. 176

Motor: as described above
Speed: 24 km/h
Shaker: 0.5 Hz
Wind: 32 km/h (2 fans on low)
Rain: 0.057 ℓ/sec.
Heat: Field winding - 10 kVA
Gear case sump - none
Ambient temperature: 21-30°C
Duration: 6 hours

Test No.	Leakage rate, ml/6-hour test		
	Commutator end reservoir	Pinion end reservoir	Gear case
176	0.3	0.1	8

Observations - Test No. 176

Condensate was noted on the inside of the commutator end reservoir window. Commutator end oil had a hazy appearance and large water drops in the oil were not clear water but seemed to be some type of emulsion. The oil in the pinion end reservoir was clear but contained some small droplets.

Test Nos. 177, 178, 179

Motor: as described above
Speed: 24 km/h
Shaker: 0.5 Hz
Wind: 32 km/h (2 fans on low)
Rain: 0.057 ℓ/sec.
Heat: Field winding - 10 kVA
Gear case sump - 3 kW
Ambient temperature: 17-23°C
Duration: 6 hours

Test No.	Leakage rate, ml/6-hour test	
	Commutator end reservoir	Pinion end reservoir
177	0	2
178	0.1	3.9
179	0.3	2.5

Observations - Test No. 177

The commutator end oil contained very fine droplets in suspension and the oil had a milky appearance. The larger water droplets were not clear water but had the appearance of an oil-water emulsion. The pinion end oil contained some fine droplets of water. Condensation was present on both reservoir windows.

Observations - Test No. 178

The commutator end oil contained droplets in suspension which were slightly larger than for Test 177 and the oil was not as hazy. Droplets were also present in the pinion end oil but were fewer in number than for test 177. Condensation was present on both reservoir windows (see Figs. 4 & 5).

Observations - Test No. 179

The commutator end oil contained many droplets. The pinion end oil also contained small drops. Condensation was present on both oil reservoir windows.

Test Nos. 180, 181

Motor: as described above
Speed: 24 km/h
Shaker: 0.5 Hz
Wind: 32 km/h (2 fans on low)
Rain: 0.057 ℓ/sec.
Heat: Field winding - 10 kVA
Gear case sump - 3 kW
Room ambient: +3°C
Duration: 6 hours

Test No.	Leakage rate, ml/6-hour test	
	Commutator end reservoir	Pinion end reservoir
180	0.1	0.9
181	0.1	1.5

Observations - Test No. 180

The oil was clear in both reservoirs but contained many droplets. In the pinion end the water in the droplets appeared to be a milky emulsion. Condensation covered 10% of the commutator end window and 75% of the pinion end window.

Observations - Test No. 181

The oil from both reservoirs contained many water droplets which had a milky colour. The oil was clear. Condensation covered 15% of the commutator end window and 60% of the pinion end window.

Test No. 182

Motor: as described above
Speed: 24 km/h
Shaker: 0.5 Hz
Wind: 32 km/h (2 fans on low)
Rain: 0.057 ℓ/sec.
Heat: Field windings - 10 kVA
Gear case sump - none
Room ambient: +3°C
Duration: 6 hours

Test No.	Leakage rate, ml/ 6-hour test	
	Commutator end reservoir	Pinion end reservoir
182	<0.1	0.9

Observations - Test No. 182

Small drops of water were present in the oil in both reservoirs. The water drops had only a slight haze to them. The oil was clear. Condensation covered 15% of the commutator end reservoir window and 20% of the pinion end reservoir window.

Test No. 183

Motor: as described above
Speed: 24 km/h
Shaker: 0.5 Hz
Wind: 32 km/h (2 fans on low)
Rain: 0.057 ℓ/sec.
Heat: Field winding - 10 kVA
Gear case sump - none
Room ambient: 17-24°C
Duration: 6 hours

Test No.	Leakage rate, ml/6-hour test	
	Commutator end reservoir	Pinion end reservoir
183	0.1	0.9

Observations - Test No. 183

The oil and the water drained from the reservoirs was clear. Condensation covered 50% of the commutator end reservoir window and 20% of the pinion end reservoir window.

Test Nos. 184, 185

Motor: as described above
Speed: 24 km/h
Shaker: 0.5 Hz
Wind: 32 km/h
Rain: 0.057 ℓ/sec.
Heat: Field winding - none
Gear case sump - none
Ambient temperature: 21-23°C

Test No.	Leakage rate, ml/6-hour test	
	Commutator end reservoir	Pinion end reservoir
184	<0.1	0.4
185	0.1	0.2

Observations - Test No. 184

The oil from the commutator end reservoir contained some droplets but was clear in colour. The oil from the pinion end reservoir was clear. The water drained from the reservoir had a milky colour. Condensation covered 25% of the commutator end reservoir window and 5% of the pinion end reservoir window.

Observations - Test No. 185

The oil from both reservoirs was free of water droplets. There was no condensation on either reservoir window. The oil reservoir sealing appeared to be intact.

Test Nos. 186, 187

Motor: as described above. The overflow vent on the gear case was blocked.
Speed: 24 km/h
Shaker: 0.5 Hz
Wind: 32 km/h
Rain: 0.057 ℓ/sec.
Heat: Field winding - 10 kVA
Gear case sump - 3 kW
Ambient temperature: 20-27°C
Duration: 6 hours

Test No.	Leakage rate, ml/6-hour test	
	Commutator end reservoir	Pinion end reservoir
186	0.3	2.7
187	0.1	4.7

Observations - Test No. 186

The oil from the commutator and pinion end reservoirs was clear. The free water from the pinion end reservoir had a milky appearance. Condensation covered 40% of the commutator end reservoir window and 80% of the pinion end reservoir window at the end of the test.

Observations - Test No. 187

The oil from both reservoirs was clear. Condensation covered 40% of the commutator end reservoir window and 80% of the pinion end reservoir window at the end of the test.

Test Nos. 188, 189

Motor: as described above. The gear case overflow vent and the seal drain were blocked.
Speed: 24 km/h
Shaker: 0.5 Hz
Wind: 32 km/h
Rain: 0.057 ℓ/sec.
Heat: Field winding - 10 kVA
Gear case sump - 3kW
Ambient temperature: 22-28°C
Duration: 6 hours

Test No.	Leakage rate, ml/6-hour test	
	Commutator end reservoir	Pinion end reservoir
188	0.3	5.9
189	0.2	7.3

Observations - Test No. 188

The oil in both reservoirs was clear. The water in the commutator end reservoir was milky in colour. The water in the pinion end reservoir was clear but had a yellow colour. At the end of the test condensation covered 40% of the commutator end reservoir window and 80% of the pinion end reservoir window.

Observations - Test No. 189

The oil in both reservoirs was clear. The water in the commutator end reservoir was milky in colour whereas the water in the pinion end reservoir was clear but yellow in colour. Condensation covered 60% of the commutator end reservoir window and 85% of the pinion end reservoir window.

Test Nos. 190, 191

Motor: as described above. Gear case overflow vent open, gear case seal drain blocked.
Speed: 24 km/h
Shaker: 0.5 Hz
Wind: 32 km/h
Rain: 0.057 ℓ/sec.
Heat: Field winding - 10 kVA
Gear case sump - 3 kW
Ambient temperature: 19-27°C
Duration: 6 hours

Test No.	Leakage rate, ml/6-hour test	
	Commutator end reservoir	Pinion end reservoir
190	0.4	2.7
191	0.1	5.3

Observations - Test No. 190

The oil in both the commutator and pinion end reservoirs was clear. The water from the commutator end reservoir had a milky colour. The water from the pinion end reservoir was a cloudy yellow colour. Condensation covered 50% of the commutator end reservoir and 80% of the pinion end reservoir at the end of the test.

Observations - Test No. 191

The oil from both reservoirs was clear. The water from the pinion end reservoir had a cloudy light yellow colour. Condensation covered 75% of the commutator end reservoir window and 85% of the pinion end reservoir window at the end of the test.

Test Nos. 192, 193

Motor: as described above - the gear case overflow vent and gear case drain openings were both open.
Speed: 24 km/h
Shaker: 0.5 Hz
Wind: 32 km/h
Rain: 0.057 ℓ/sec.
Heat: Field winding - none
Gear case sump - none
Ambient temperature: 15-24°C
Duration: 6 hours

Test No.	Leakage rate, ml/6-hour test		
	Commutator end reservoir	Pinion end reservoir	Gear case
192	0.2	2.5	44
193	0.4	0.6	27

Observations - Test No. 192

Condensation covered 50% of both the commutator and pinion end reservoir windows.

Observations - Test No. 193

The water removed from both bearing reservoirs was milky in colour.

Test No. 194

Motor: as described above. Gear case pressurized to 100 pascals (0.4" H_2O) with air.
Speed: 24 km/h
Shaker: 0.5 Hz
Wind: 32 km/h
Rain: 0.057 ℓ/sec.
Heat: Field winding - 10 kVA
Gear case sump - 3 kW for first 2.5 hours of test only, at which time heater failed.
Duration: 6 hours

Test No.	Leakage rate, ml/6-hour test	
	Commutator end reservoir	Pinion end reservoir
194	0.1	1.1

Observations - Test No. 194

Condensation covered 60% of commutator end reservoir window and 70% of pinion end reservoir window at end of test.

Test Nos. 195, 196

Motor: as described above. Gear case was pressurized to 100 pascals (0.4" H_2O) with air. Gear case overflow vent and seal drain were open.
Speed: 24 km/h
Shaker: 0.5 Hz
Wind: 32 km/h
Rain: 0.057 ℓ/sec.
Heat: Field winding - none
Gear case sump - none
Ambient Temperature: 18-23°C
Duration: 6 hours

Test No.	Leakage rate, ml/6-hour test		
	Commutator end reservoir	Pinion end reservoir	Gear case
195	0.1	<0.1	2.5
196	0.1	0.1	0.5

Observations - Test No. 195

All oil and water was clear. There was no condensation on the reservoir windows.

Observations - Test No. 196

All oil and water samples were clear. There was no condensation on the reservoir windows.