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SR 96

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EVALUATION OF THE AASHO PROFILOMETER FOR MEASURING AIRFIELD PAVEMENT PROFILES

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E. J. Yoder

and

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APRIL 1966

Conducted for
CORPS OF ENGINEERS, U. S. ARMY
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COLD REGIONS RESEARCH & ENGINEERING LABORATORY
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PREFACE

Authority for the investigation reported herein is contained in FY 1959 Instructions and Outline, Military Construction Investigations, Engineering Criteria and Investigations and Studies, Studies of Construction in Areas of seasonal Frost: Field Investigations.

The study was conducted for the Office, Chief of Engineers, Directorate of Military Construction by the Purdue Research Foundation, School of Civil Engineering, Purdue University, Lafayette, Indiana, under a contract awarded by the former Arctic Construction and Frost Effects Laboratory (ACFEL).* Project responsibility was transferred to the U. S. Army Cold Regions Research and Engineering Laboratory (USA CRREL) after completion of the study. Professor Eldon J. Yoder was the principal investigator for the Purdue Research Foundation. Cooperation of personnel of the AASHO Road Test, Ottawa, Illinois, in conducting the field tests, and assistance in interpreting the results is gratefully acknowledged.

This report was prepared by the Construction Engineering Branch, Mr. E. F. Lobacz, Chief (Former Coordinator, ACFEL), as a project of the Experimental Engineering Division, Mr. K. A. Linell, Chief (Former Director, ACFEL), USA CRREL. Mr. G. D. Gilman of the Construction Engineering Branch was responsible for coordination of the final report.

Colonel Philip G. Krueger was Commanding Officer of USA CRREL during the preparation and publication of this report, and Mr. W. K. Boyd was Technical Director.

USA CRREL is an Army Materiel Command laboratory.

*ACFEL and U. S. Army Snow, Ice and Permafrost Research Establishment (USA SIPRE) were merged into the Cold Regions Research and Engineering Laboratory (USA CRREL), Hanover, New Hampshire, in 1961.

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EVALUATION OF THE AASHO PROFILOMETER FOR MEASURING AIRFIELD PAVEMENT PROFILES

by

E. J. Yoder and R. D. Walker

INTRODUCTION

Background

Under an earlier contract with the former Arctic Construction and Frost Effects Laboratory of the U. S. Army Engineer Division, New England, the Purdue Research Foundation conducted a literature search and evaluation of methods which have been employed for measuring pavement profiles and roughness. Results of the study are contained in ACFEL Technical Report 73, "Pavement Profile and Roughness Measurements (A Review of Methods)" by E. J. Yoder and D. Hampton, June 1960.

Under the previous contract, existing instruments were reviewed in terms of mobility, durability, accuracy of both profile and roughness measurements, and usability of data produced. No instrument was found to be completely satisfactory in these respects and it was considered that the method of greatest potential was a profilometer that measures slope angles using an inertial system to maintain a suitable vertical or horizontal reference plane. At the time the study was being conducted, such an instrument was under development at the AASHO Road Test, Ottawa, Illinois, and liaison with AASHO regarding this device was recommended.

Subsequent liaison between ACFEL and AASHO Road Test personnel indicated that an evaluation of the capability of the AASHO profilometer to measure airfield pavement profiles was warranted. Accordingly the cooperation of AASHO was obtained and, in April 1959, ACFEL awarded contract DA-19-016-Eng-6554, "Study and Report on Applicability of the AASHO Profilometer for Measuring Airfield Pavement Profiles," to the Purdue Research Foundation, School of Civil Engineering, Purdue University. This report summarizes studies conducted under the contract.

Purpose and scope

The purpose of this study was to determine the capability of the AASHO profilometer to measure airfield pavement profiles. To accomplish this, a number of test tracks were established on pavements at Chanute AFB, Rantoul, Illinois, and profiles obtained with the AASHO instrument were compared with those obtained using standard precise level procedures.

THE AASHO PROFILOMETER

Figure 1 shows the profilometer and towing vehicle, containing electronic recording instrumentation, in operation. Profiling is normally accomplished at a speed of about 5 mph.

The instrument contains an inertial system for continuous horizontal reference and two reference slope or "feeler" wheels, mounted in tandem between each of two pairs of motorcycle wheels (Fig. 1), which measure abrupt changes in profile. The inertial horizontal reference system adopted for the AASHO profilometer is based upon the principle of a floating, spinning disk. The disk is mounted on a center pivot through which air is permitted to escape at high velocity which in turn acts as a lubricant between disk and pivot.

The disk is caused to rotate at high speed and, since it is lifted from the pivot by the air pressure, it in effect acts as a gyroscope.

Referring to the schematic diagram on Figure 2, the inertial system "R" detects the angle "B" between the trailer and an imaginary horizontal reference; and the slope wheels "S" measure the angle "A" between the axle of the slope wheels and the frame. Prior tests by AASHO Road Test personnel of the effectiveness of the horizontal reference system had indicated that the inconvenience of operation with the reference was considerable. It is pertinent to note, therefore, that testing at the Ottawa Road Test was generally accomplished without the horizontal reference system in operation.

The instrument produces a continuous analog of the slope of the pavement (Fig. 3, 4) in two wheel paths which correspond to the tread of an automobile. The analog tapes are fed into an automatic electronic tape reader which measures the ordinate of the chart at intervals equivalent to 1 ft on the pavement.

As previously stated, the profilometer data on the AASHO Road Test were analyzed without using the output of the horizontal reference system. The profile characteristics were reduced to a single statistic by use of the equation:

$$\overline{SV} = \frac{\Sigma Y^2 - \frac{1}{n}(\Sigma Y)^2}{n-1}$$

where: Y is the difference between elevations 1 ft apart, and
n is the number of readings.

Slope variance $\overline{SV}$ as given by the equation is the statistical variation of slope at 1 ft intervals referenced to the mean slope of an entire test pavement. The slope variance statistic is indicative of pavement roughness, but does not consider long wave lengths of the pavement.

EVALUATION TESTS

The testing schedule at the AASHO Road Test limited the availability of the profilometer and operating crew to a period not exceeding 5 days, including travel time. Permission was obtained from the Commander, Chanute Air Force Base, Rantoul, Illinois, to conduct the evaluation tests on pavements at that installation during the period 26-30 October 1959.

Procedure

Eight test tracks were established on portland cement concrete pavements on the NW end of the NW-SE runway and on adjoining taxiway A. Two of the tracks were 400 ft long, four were 800 ft long, one was 1300 ft long, and one curved track approximately 268 ft in length was established along a painted traffic line. The locations of the test tracks are shown on Figure 5 and will hereinafter be referred to by the track numbers shown on Figure 5. With the exception of the curved track, the courses were established along longitudinal joints to permit the driver to line up along the joint. This resulted in passage of the left pair of slope wheels approximately 3 in. from the joint, and passage of the right pair of slope wheels approximately in the middle of the slabs, which were 12.5 ft wide.

Measurements of elevation accurate to about ±.002 ft were made along both wheel paths of the profilometer using a precise level and static rod with target. Level readings were taken at intervals ranging from 1 ft to 100 ft, with the larger portion of the data obtained in the left wheel path of the profilometer.

As previously stated, the AASHO profilometer contains an inertial system for continuous horizontal reference and two slope wheels which measure abrupt changes in profile. Three types of measurement were made with the profilometer. Profiles were run using both measurement systems and with each system operating alone to determine which of the systems had the greatest effect on the results.

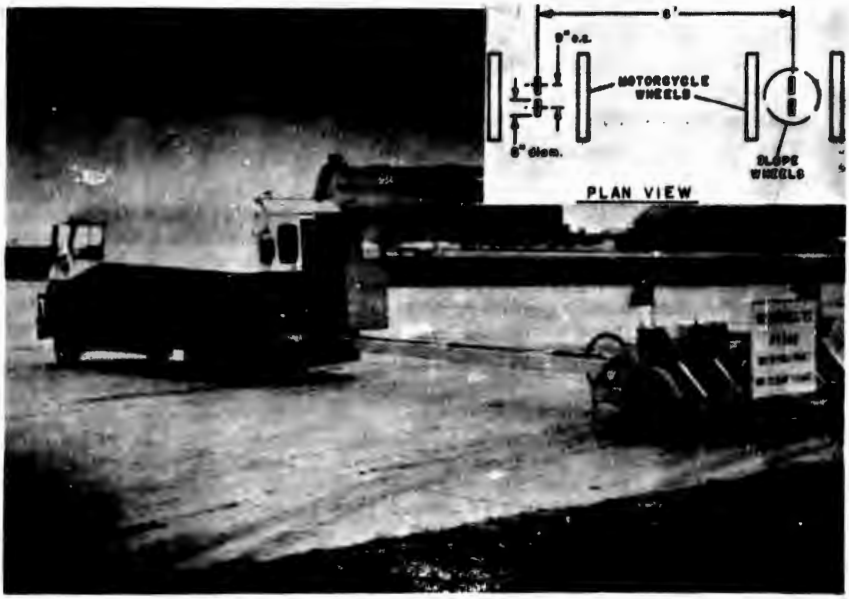

Figure 1. AASHO profilometer in operation.

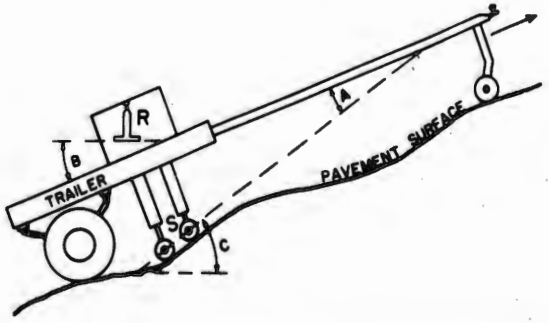

Figure 2. Schematic diagram of profilometer.

The profilometer was towed over each of the eight tracks a minimum of three times and at least one run was made on each track with both systems in operation. Two runs were made on tracks 5 and 6 using the horizontal reference only and several tests were made on each track with only the slope wheels in operation.

Table I. Profilometer test runs.

Measurement system operating	Test Track 1	2	3	4	5	6	7	8
Horizontal reference and slope wheels	1	1	1	1	3	2	1	2
Slope wheels only	2	2	2	3	4	2	2	2
Horizontal reference only	0	0	0	0	2	2	0	0

The analog charts produced by the profilometer were later read electronically in the Road Test laboratories. This information was fed into a digital computer which summarized the slope data in units of feet per foot; elevations were expressed by making a continuous summation of the slope data. Since the method adopted at the Road Test for representing pavement profile is based upon mean slope of the test track, as shown by the equation previously given, it was then necessary to recalculate the data to relate these elevations to the level elevations at specific locations along the test tracks. This operation may have introduced some error; however, the amount is not known.

Results

The comparative elevations obtained by profilometer and level for the various test tracks and wheel paths are shown on Figures A1 to A16 (App A) and are summarized on Tables BI to BXVI (App B). The following analysis of the profilometer capabilities is made on a qualitative basis by comparing the general profiles obtained by each method of measurement to the level data.

From the test results it is evident that it is necessary to use the horizontal reference system, since data produced by the slope wheels alone did not compare favorably with the level data. This would be expected since these wheels measure slopes relative to the frame of the device itself. Test runs with only the horizontal reference system in operation gave better results, but again the profiles were in general different from those obtained by leveling.

The best results were obtained when the slope wheels and horizontal reference systems were both operating. The results of these runs are summarized in Table II: Profilometer results are considered to be entirely inadequate only for track 8. It is significant to note that track 8 was a horizontal curve which may have introduced error into the data produced by the profilometer.

With both measurement systems in operation, the general shape of profiles produced by the profilometer on tracks 1 through 7 compared favorably with those obtained by precise leveling techniques. The profilometer comparison to the true profile was considered excellent on track 7, where the profiles were almost identical, and good on track 3. However, numerical values of elevation produced by the profilometer on tracks 1, 2, 4, 5 and 6 were not in good agreement with the precise level values. Observation of Figure A1 suggests that errors may accumulate in the horizontal reference system. It will be noted that the slope of the profile obtained from profilometer run 5-HR is essentially the same as the level profile, but that an accumulative error apparently occurred in the first 40 ft of test run. These data further suggest that if the profilometer could be re-referenced at intervals to level check points, profiles produced by the two methods would be essentially the same. The same observation can be made for all the other test runs except those on track 8.

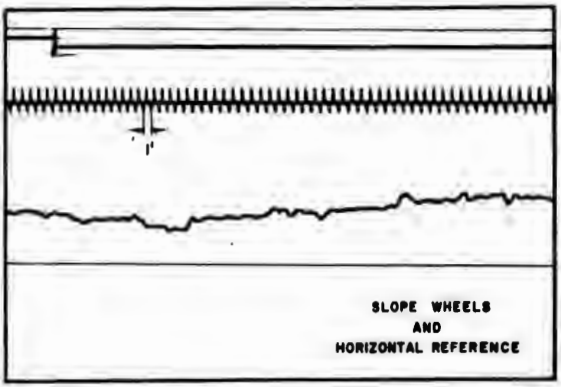

Figure 3. Profilometer analog chart.

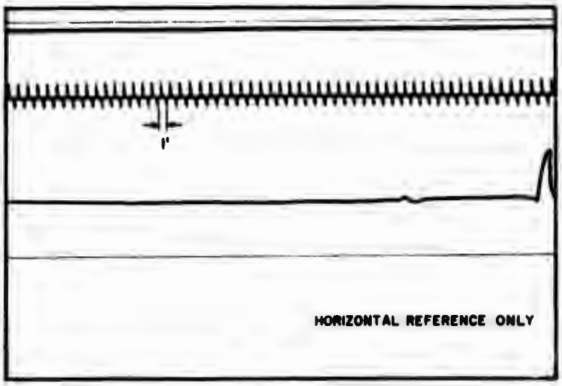

Figure 4. Profilometer analog chart.

Table II. Summary of profilometer runs with horizontal reference and slope wheels in operation.

Track	Wheel path	Max diff between level and prof data (ft)	General rating of profilometer data	Remarks
1	Left	0.2	Fair	Approximate profile reproduced, accumulative errors present
1	Right	1.1	Fair	Approximate profile reproduced, accumulative errors present
2	Left	0.7	Fair	Approximate profile reproduced, accumulative errors present
2	Right	0.5	Fair	Approximate profile reproduced, accumulative errors present
3	Left	0.2	Good	Approximate profile reproduced, accumulative errors present
3	Right	0.2	Good	Approximate profile reproduced, accumulative errors present
4	Left	1.0	Fair	Approximate profile reproduced, accumulative errors present
4	Right	0.8	Fair	Approximate profile reproduced, accumulative errors present
5	Left	3.5*	Fair	Runs 1 and 2 good, run 3 poor
5	Right	2.5*	Fair	Runs 1 and 2 good, run 3 poor
6	Left	1.0	Fair	Approximate profile reproduced
6	Right	1.0	Fair	Approximate profile reproduced
7	Left	0.1	Excellent	Approximate profile reproduced
7	Right	0.3	Good	Approximate profile reproduced
8	Left	1.3	Very poor	Did not reproduce slope of profile
8	Right	1.1	Very poor	Did not reproduce slope of profile

*Run No. 3

CONCLUSIONS

It is apparent that the accuracy of the profilometer is to a large extent dependent on the accuracy of the horizontal reference system.

Results of these tests indicate that differences between level and profilometer data are the result of accumulated errors in the horizontal reference system; however, the reason for the errors did not become apparent during the course of this study. There appears to be little doubt that use of a precise gyroscope would eliminate most of the accumulated errors introduced by the present reference system.

RECOMMENDATIONS

The AASHO profilometer is sound in principle, and it is recommended that this type of instrument be adopted if fabrication of a profilometer for use on airfield pavements is undertaken by the Government. However, further development of the horizontal reference system is necessary, and development of a system incorporating precise gyroscopes is recommended. The data obtained in this study indicate that such an instrument will reproduce profiles, and will have wide application for use on airfield pavements.

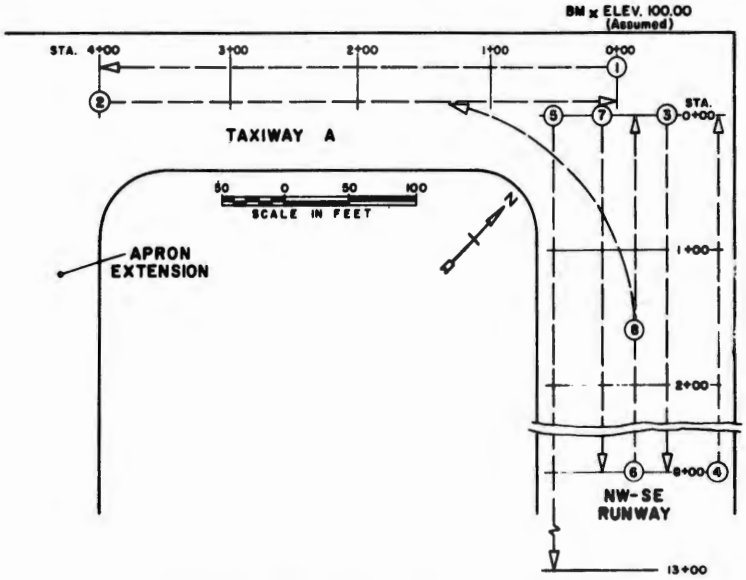

Figure 5. Location of test tracks, Chanute AFB. Tracks established along longitudinal joints. Left wheel path approximately 3 in. from joint. Right wheel path 6 ft to right in direction of travel.

APPENDIX A. PROFILES BY LEVEL AND PROFILOMETER

LEGEND

HR Horizontal Reference and slope wheels operating

NHR Horizontal Reference Not Operating, slope wheels only

HRO Horizontal Reference Operating, slope wheels not operating

Number designates profilometer run.

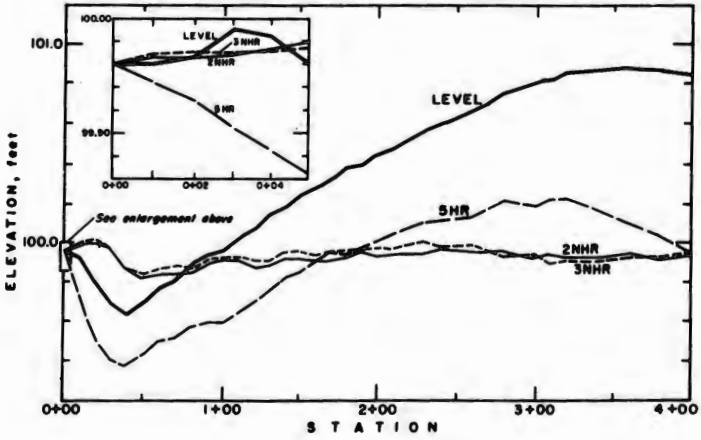

Figure A1. Track 1, left wheel path.

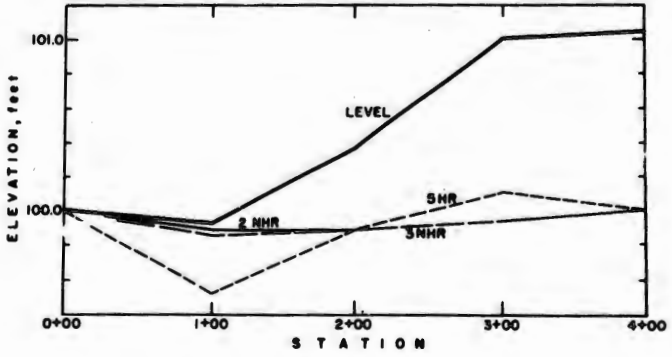

Figure A2. Track 1, right wheel path.

APPENDIX A

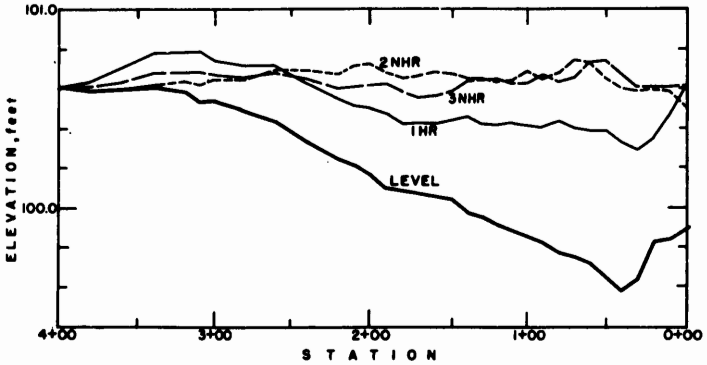

Figure A3. Track 2, left wheel path.

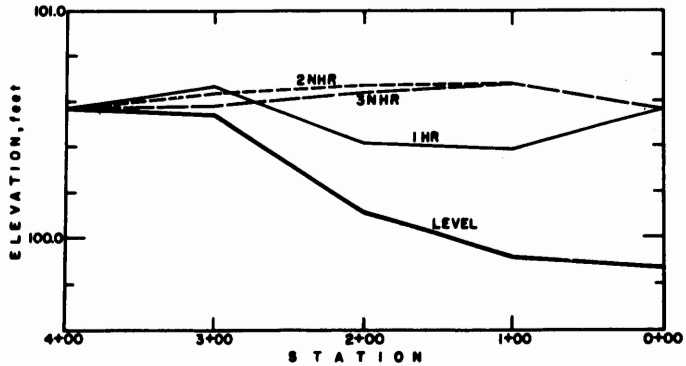

Figure A4. Track 2, right wheel path.

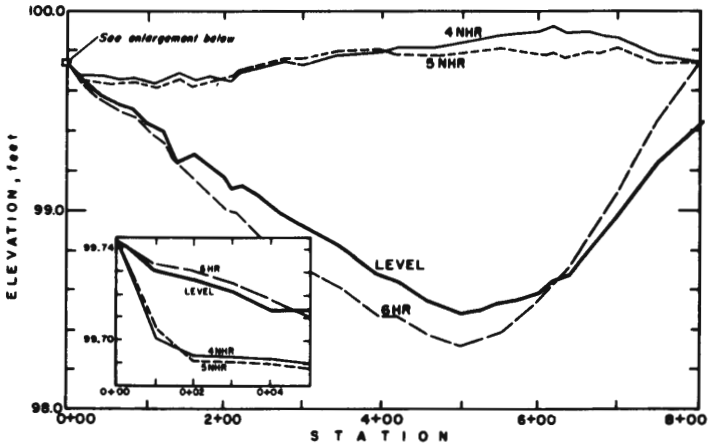

Figure A5. Track 3, left wheel path.

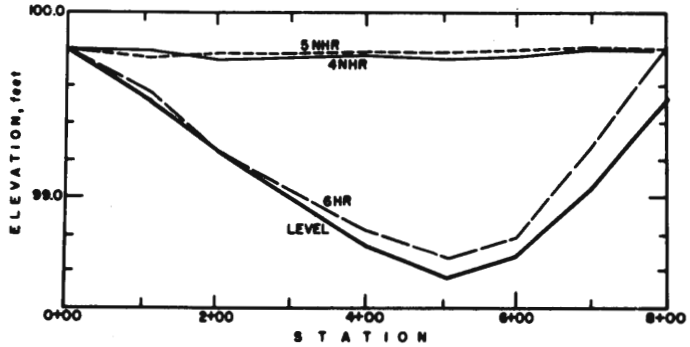

Figure A6. Track 3, right wheel path.

APPENDIX A

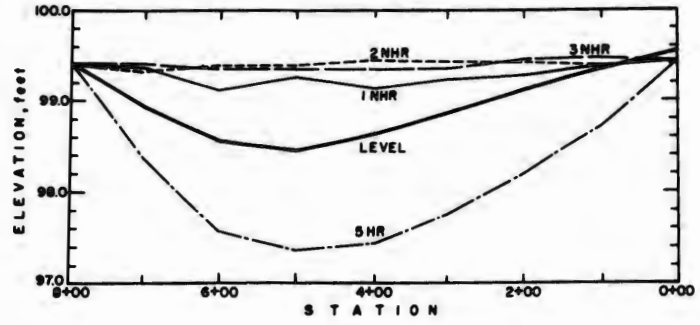

Figure A7. Track 4, left wheel path.

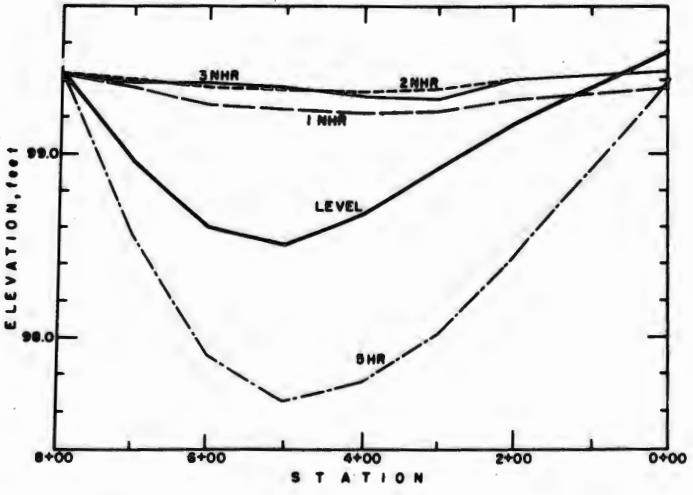

Figure A8. Track 4, right wheel path.

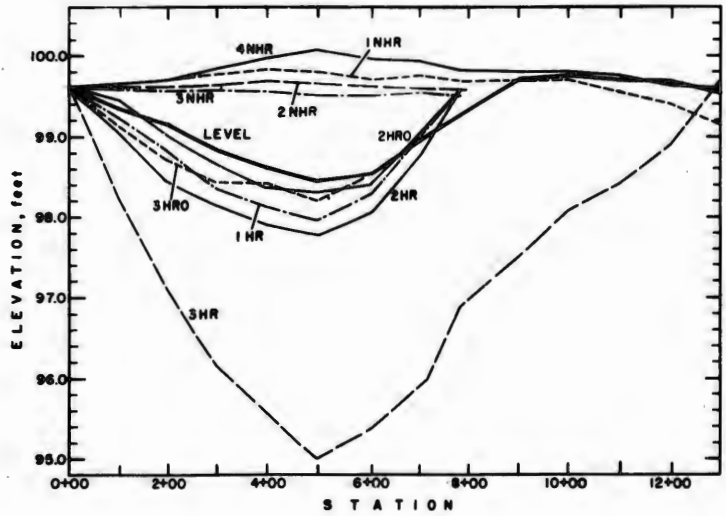

Figure A9. Track 5, left wheel path.

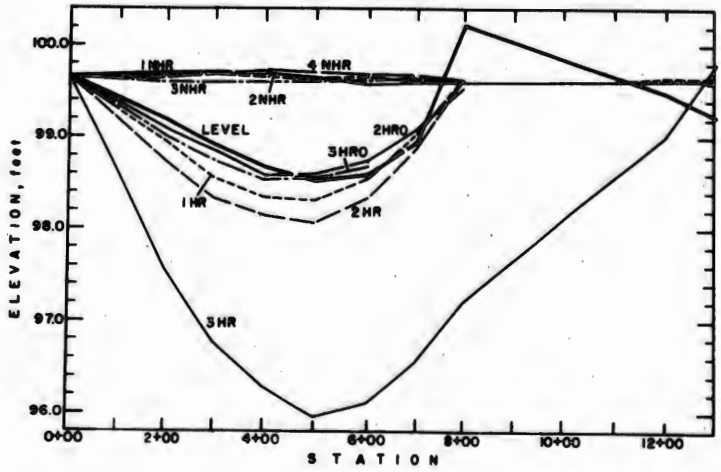

Figure A10. Track 5, right wheel path.

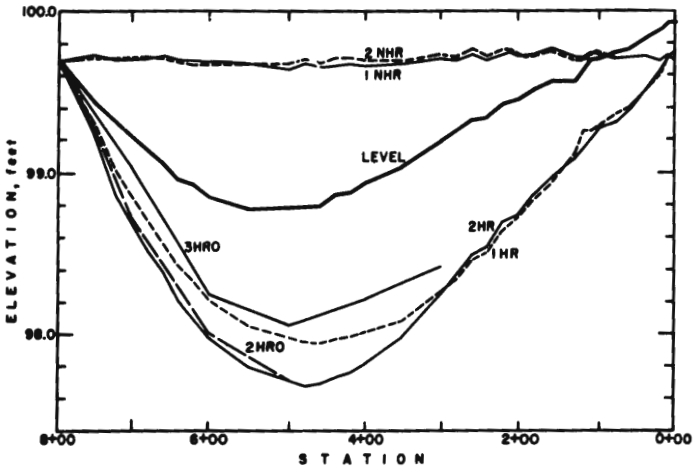

Figure A11. Track 6, left wheel path.

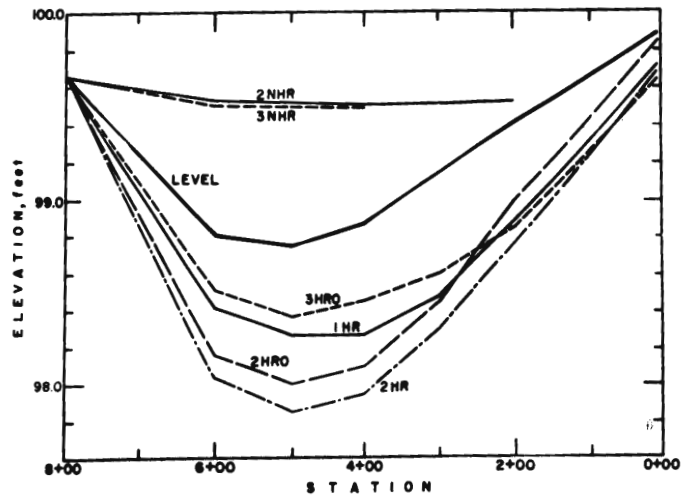

Figure A12. Track 6, right wheel path.

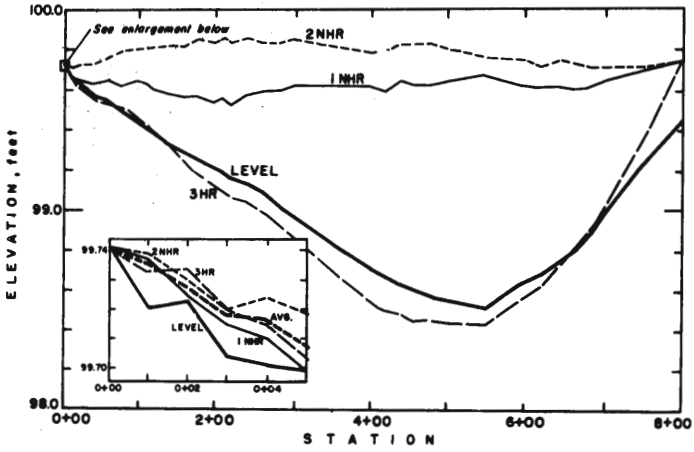

Figure A13. Track 7, left wheel path.

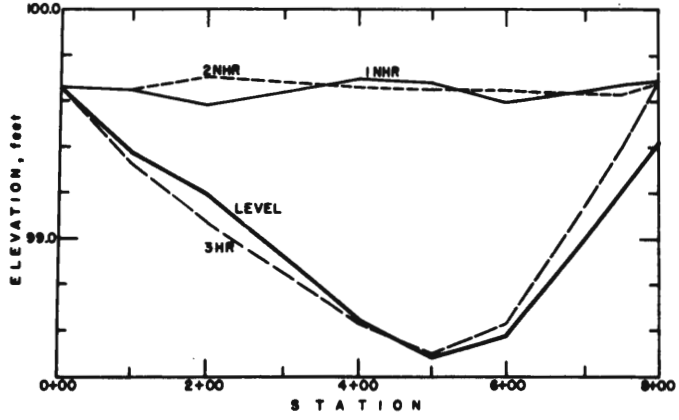

Figure A14. Track 7, right wheel path.

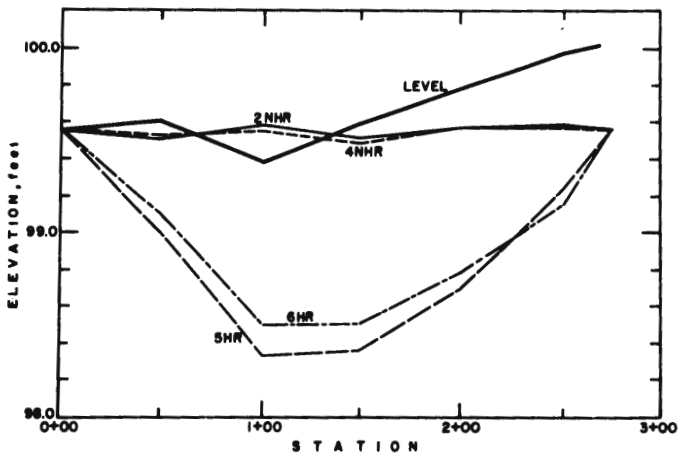

Figure A15. Track 8, left wheel path.

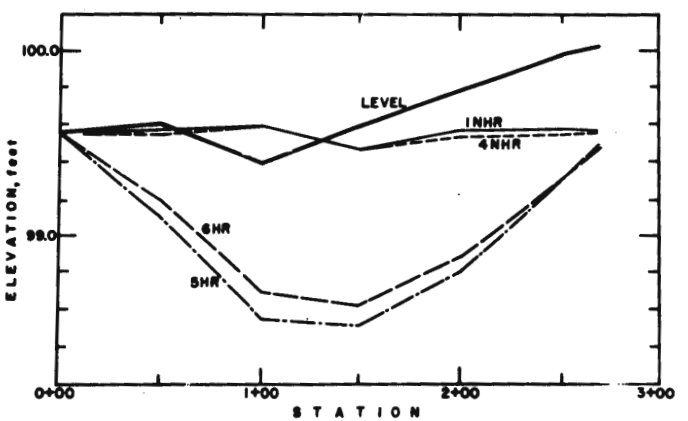

Figure A16. Track 8, right wheel path.

LEGEND

HR Horizontal Reference and slope wheels operating

NHR Horizontal Reference Not Operating, slope wheels only

HRO Horizontal Reference Operating, slope wheels not operating

Number designates profilometer run.

Table BI. Track 1, left wheel path.

Station	Level	Profilometer 5-HR	2-NHR	3-NHR
0/00	99.961	99.961	99.961	99.961
01	99.961	99.946	99.966	99.968
02	99.966	99.928	99.966	99.970
03	99.990	99.904	99.968	99.969
04	99.984	99.884	99.972	99.971
05	99.962	99.863	99.976	99.974
06	99.970	99.843	99.985	99.979
07	99.958	99.822	99.992	99.984
08	99.944	99.802	100.000	99.990
09	99.939	99.772	100.004	99.996
10	99.928	99.743	100.008	99.997
15	99.849	99.616	100.003	99.995
20	99.800	99.531	100.017	99.999
25	99.750	99.473	100.003	99.986
30	99.699	99.411	99.982	99.970
35	99.649	99.375	99.932	99.921
40	99.638	99.305	99.071	99.864
45	99.656	99.404	99.848	99.839
50	99.696	99.439	99.841	99.826
60	99.765	99.500	99.864	99.839
70	99.817	99.522	99.881	99.849
80	99.885	99.584	99.076	99.852
90	99.931	99.604	99.924	99.899
1/00	99.963	99.608	99.936	99.922
01	99.963	99.611	99.937	99.925
02	99.965	99.619	99.939	99.929
03	99.969	99.622	99.943	99.925
04	99.974	99.618	99.946	99.923
05	99.980	99.618	99.950	99.919
10	100.002	99.650	99.950	99.910
15	99.983	99.675	99.921	99.894
20	100.075	99.705	99.917	99.878
30	100.136	99.768	99.919	99.895
40	100.175	99.823	99.952	99.914
50	100.232	99.856	99.960	99.913
60	100.277	99.910	99.949	99.913
70	100.324	99.960	99.966	99.912
80	100.362	99.960	99.952	99.930
90	100.400	99.973	99.971	99.960
2/00	100.446	100.013	99.988	99.945
01	100.457	100.018	99.982	99.945
02	100.456	100.022	99.981	99.946
03	100.462	100.031	99.976	99.945
04	100.465	100.036	99.975	99.944
05	100.464	100.044	99.977	99.943
10	100.486	100.055	99.981	99.954
20	100.527	100.067	99.997	99.958
30	100.572	100.118	100.006	99.954
40	100.603	100.127	99.994	99.979
60	100.679	100.143	99.995	99.968
80	100.764	100.216	99.942	99.962
3/00	100.817	100.196	99.942	99.935
01	100.819	100.199	99.941	99.935
02	100.825	100.203	99.940	99.935
03	100.827	100.204	99.941	99.935
04	100.825	100.209	99.942	99.939
05	100.824	100.216	99.921	99.936
10	100.835	100.223	99.909	99.945
20	100.868	100.220	99.911	99.939
40	100.872	100.176	99.919	99.934
60	100.879	100.101	99.932	99.948
80	100.871	100.035	99.939	99.920
4/00	100.849	99.959	99.955	99.946

Table BII. Track 1, right wheel path.

Station	Level	Profilometer 5-HR	2-NHR	3-NHR
0/00	100.006	100.006	100.006	100.006
10	99.929	99.839	100.051	100.033
20	99.806	99.628	100.066	100.041
30	99.691	99.449	100.015	99.985
40	99.631	99.333	99.919	99.880
50	99.696	99.366	99.916	99.872
60	99.751	99.415	99.910	99.856
70	99.801	99.431	99.686	99.837
80	99.866	99.485	99.916	99.871
90	99.897	99.511	99.920	99.879
1/00	99.931	99.524	99.903	99.868
10	99.797	99.371	99.897	99.869
20	100.038	99.620	99.907	99.871
30	100.094	99.669	99.918	99.885
40	100.124	99.704	99.907	99.881
50	100.159	99.732	99.899	99.871
60	100.218	99.791	99.901	99.882
70	100.258	99.832	99.903	99.894
80	100.312	99.846	99.915	99.904
90	100.331	99.881	99.900	99.894
2/00	100.366	99.893	99.899	99.900
20	100.696	99.950	99.904	99.904
40	100.781	99.952	99.926	99.922
60	100.850	100.061	99.919	99.932
80	100.929	100.093	99.939	99.943
3/00	101.003	100.116	99.957	99.948
20	101.047	100.144	99.973	99.965
40	101.057	100.122	99.972	99.959
60	101.061	100.095	99.986	99.973
80	101.054	100.057	99.967	99.958
4/00	101.044	100.006	100.001	100.002

APPENDIX B

Table BIII. Track 2, left wheel path.

Station	Level	Profilometer 1-HR	2-HRR	3-HRR
4/00	100.608	100.608	100.608	100.608
3/80	100.584	100.632	100.600	100.590
60	100.593	100.701	100.595	100.603
40	100.608	100.781	100.618	100.642
20	100.585	100.784	100.635	100.637
10	100.531	100.787	100.614	100.655
05	100.537	100.771	100.623	100.618
3/00	100.537	100.742	100.645	100.624
2/80	100.489	100.716	100.642	100.608
60	100.435	100.715	100.693	100.638
40	100.329	100.627	100.690	100.635
20	100.246	100.549	100.677	100.585
10	100.212	100.516	100.713	100.601
05	100.205	100.510	100.712	100.604
04	100.204	100.508	100.715	100.611
03	100.194	100.513	100.715	100.613
02	100.182	100.513	100.715	100.616
01	100.180	100.509	100.731	100.620
2/00	100.171	100.503	100.724	100.615
1/95	100.145	100.493	100.693	100.627
90	100.103	100.473	100.681	100.624
85	100.098	100.457	100.684	100.593
80	100.087	100.422	100.653	100.582
70	100.071	100.428	100.664	100.553
1/60	100.058	100.425	100.683	100.565
50	100.038	100.442	100.675	100.587
40	99.977	100.459	100.652	100.636
30	99.953	100.423	100.653	100.638
20	99.919	100.416	100.637	100.647
10	99.884	100.429	100.641	100.625
1/00	99.853	100.416	100.687	100.623
99	99.858	100.416	100.667	100.623
98	99.853	100.416	100.664	100.629
97	99.852	100.416	100.660	100.636
96	99.852	100.416	100.660	100.642
95	99.855	100.413	100.651	100.647
90	99.823	100.407	100.647	100.671
85	99.792	100.429	100.667	100.650
80	99.775	100.425	100.679	100.636
70	99.752	100.500	100.748	100.658
60	99.718	100.390	100.727	100.732
50	99.648	100.387	100.650	100.739
40	99.582	100.330	100.603	100.669
30	99.638	100.289	100.588	100.608
20	99.826	100.349	100.593	100.591
10	99.839	100.477	100.587	100.605
0/00	99.889	100.608	100.506	100.607

Table BIV. Track 2, right wheel path.

Station	Level	Profilometer 1-HR	2-HRR	3-HRR
4/00	100.560	100.560	100.560	100.560
3/80	100.566	100.626	100.585	100.585
60	100.567	100.656	100.579	100.570
40	100.563	100.685	100.593	100.572
20	100.540	100.707	100.640	100.599
3/00	100.541	100.663	100.635	100.588
2/90	100.489	100.627	100.612	100.558
80	100.437	100.644	100.627	100.567
60	100.438	100.624	100.683	100.623
40	100.256	100.498	100.643	100.573
20	100.168	100.430	100.624	100.604
2/00	100.111	100.411	100.672	100.635
1/90	100.037	100.367	100.634	100.608
80	100.045	100.381	100.639	100.603
70	100.018	100.383	100.614	100.604
60	100.017	100.395	100.658	100.662
50	99.988	100.401	100.682	100.667
40	99.917	100.351	100.636	100.631
30	99.900	100.368	100.654	100.652
20	99.901	100.390	100.657	100.648
10	99.863	100.382	100.657	100.642
1/00	99.918	100.369	100.678	100.673
90	99.813	100.371	100.670	100.655
80	99.785	100.354	100.661	100.665
70	99.752	100.338	100.686	100.692
60	99.696	100.297	100.708	100.706
50	99.648	100.260	100.704	100.675
40	99.574	100.206	100.600	100.581
30	99.604	100.249	100.539	100.538
20	99.697	100.362	100.535	100.521
10	99.802	100.471	100.546	100.534
0/00	99.870	100.559	100.561	100.562

Table BV. Track 3, left wheel path.

Station	Level	Profilometer 6-MR	4-MMR	5-MMR
0/00	99.744	99.744	99.744	99.744
01	99.730	99.733	99.701	99.704
02	99.726	99.730	99.693	99.691
03	99.721	99.725	99.693	99.691
04	99.713	99.718	99.692	99.690
05	99.713	99.710	99.690	99.688
10	99.693	99.686	99.684	99.677
20	99.642	99.633	99.672	99.654
40	99.588	99.564	99.673	99.646
60	99.544	99.516	99.657	99.642
80	99.503	99.473	99.659	99.648
1/00	99.434	99.405	99.646	99.632
05	99.418	99.387	99.641	99.624
10	99.410	99.374	99.638	99.619
20	99.393	99.334	99.656	99.638
40	99.232	99.232	99.681	99.661
60	99.283	99.162	99.659	99.617
80	99.221	99.095	99.679	99.645
2/00	99.161	99.016	99.652	99.662
05	99.141	99.003	99.655	99.668
10	99.114	99.992	99.658	99.673
20	99.123	98.969	99.693	99.707
40	99.079	98.897	99.711	99.731
75	98.982	98.792	99.753	99.761
3/00	98.925	98.718	99.737	99.766
01	98.922	98.720	99.738	99.766
02	98.924	98.718	99.742	99.770
03	98.923	98.719	99.744	99.774
04	98.925	98.721	99.748	99.777
05	98.923	98.725	99.753	99.784
50	98.819	98.611	99.785	99.802
4/00	98.674	98.472	99.792	99.806
20	98.641	98.462	99.812	99.788
60	98.542	98.374	99.825	99.785
5/00	98.488	98.323	99.847	99.798
01	98.489	98.323	99.846	99.798
02	98.486	98.322	99.848	99.799
03	98.485	98.326	99.846	99.798
04	98.489	98.325	99.851	99.801
05	98.487	98.325	99.851	99.780
50	98.543	98.396	99.880	99.811
6/00	98.589	98.546	99.903	99.798
20	98.646	98.637	99.912	99.791
40	98.692	98.721	99.890	99.777
60	98.776	98.844	99.896	99.793
80	98.869	98.966	99.874	99.790
7/00	98.963	99.082	99.867	99.813
01	98.963	99.085	99.864	99.812
02	98.965	99.091	99.864	99.812
03	98.967	99.095	99.864	99.811
04	98.972	99.100	99.861	99.808
05	98.974	99.102	99.859	99.806
50	99.228	99.447	99.787	99.737
8/00	99.420	99.739	99.741	99.737

Table BVI. Track 3, right wheel path.

Station	Level	Profilometer 6-MR	4-MMR	5-MMR
0/00	99.804	99.804	99.804	99.804
1/00	99.517	99.565	99.798	99.767
2/00	99.254	99.258	99.751	99.779
4/00	98.735	98.821	99.770	99.798
5/05	98.563	98.674	99.758	99.789
6/00	98.678	98.780	99.772	99.802
7/00	99.040	99.266	99.802	99.807
8/00	99.502	99.805	99.802	99.804

Table BVII. Track 4, left wheel path.

Station	Level	Profilometer 5-MR	1-MMR	2-MMR	3-MMR
8/00	99.408	99.508	99.408	99.407	99.408
7/00	98.953	98.376	99.362	99.341	99.396
6/00	98.564	97.560	99.101	99.361	99.355
5/00	98.450	97.354	99.262	99.389	99.362
4/00	98.620	97.429	99.136	99.440	99.342
3/00	98.872	97.763	99.227	99.425	99.356
2/00	99.104	98.196	99.272	99.423	99.458
1/00	99.337	98.713	99.151	99.372	99.469
0/05	99.492	99.339	99.416	99.394	99.409
04	99.501	99.350	99.412	99.395	99.410
03	99.504	99.359	99.407	99.392	99.413
02	99.510	99.373	99.407	99.394	99.417
01	99.512	99.388		99.399	99.410
0/00	99.516	99.406		99.404	99.412

Table BVIII. Track 4, right wheel path.

Station	Level	Profilometer 5-MR	1-MMR	2-MMR	3-MMR
8/00	99.449	99.449	99.449	99.449	99.449
7/00	98.965	98.568	99.383	99.415	99.408
6/00	98.606	97.902	99.273	99.377	99.389
5/00	98.506	97.653	99.251	99.367	99.370
4/00	98.674	97.763	99.234	99.344	99.334
3/00	98.919	98.057	99.242	99.361	99.315
2/00	99.167	98.437	99.306	99.419	99.409
0/00	99.567	99.387	99.375	99.454	99.461

APPENDIX B

Table BIX. Track 5, left wheel path.

Station	Level	Profilometer								
		1-[illegible]	2-[illegible]	3-[illegible]	1-[illegible]	2-[illegible]	3-[illegible]	4-[illegible]	2-[illegible]	3-[illegible]
0/00	99.624	99.624	99.624	99.624	99.624	99.624	99.624	99.624	99.624	99.624
1/00	99.387	99.282	99.056	99.227	99.681	99.635	99.608	99.651	99.270	99.152
2/00	99.141	98.858	98.575	97.085	99.755	99.657	99.627	99.772	99.000	98.878
3/00	98.853	98.389	98.141	96.131	99.802	99.678	99.652	99.866	98.676	98.625
4/00	98.614	98.118	97.911	95.578	99.889	99.732	99.626	99.989	98.469	98.498
5/00	98.453	97.991	97.780	95.196	99.858	99.713	99.579	100.040	98.435	98.416
6/00	98.528	98.303	98.069	95.406	99.760	99.691	99.585	99.999	98.578	98.600
7/00	98.910	98.928	98.782	95.991	99.791	99.677	99.638	99.968	99.014	99.024
8/00	99.406	99.629	99.625	96.868	99.733	99.639	99.567	99.866	99.631	99.630
9/00	99.736			97.541	99.739			99.845		
10/00	99.780			98.012	99.790			99.835		
12/00	99.431			98.936	99.701			99.694		
13/00	99.244			99.759	99.623			99.634		

Table BX.. Track 5,right wheel path.

Station	Level	Profilometer								
		1-[illegible]	2-[illegible]	3-[illegible]	1-[illegible]	2-[illegible]	3-[illegible]	4-[illegible]	2-[illegible]	3-[illegible]
0/00	99.680	99.680	99.650	99.650	99.650	99.650	99.650	99.650	99.650	99.650
2/00	99.184	98.953	98.758	97.529	99.691	99.672	99.624	99.680	99.114	99.015
3/00	98.911	98.547	98.330	96.747	99.701	99.692	99.614	99.700	98.829	98.767
4/00	98.671	98.343	98.139	96.277	99.694	99.668	99.611	99.718	98.678	98.653
5/00	98.506	98.311	98.081	95.958	99.649	99.635	99.625	99.705	98.618	98.579
6/00	98.589	98.544	98.341	96.108	99.591	99.653	99.640	99.688	98.715	98.738
7/00	98.951	99.043	98.896	96.555	99.612	99.625	99.645	99.682	99.131	99.136
8/00	100.254	99.654	99.655	97.204	99.608	99.591	99.647	99.634	99.642	99.653
12/00	99.480			99.029	99.634	99.641				
13/00	99.244			99.759	99.633	99.663				

APPENDIX B

Table BXI. Track 6, left wheel path.

Station	Level	Profilometer						
		1-NR	2-NR	1-NRR	2-NRR	2-NRO	1-NRO	Average*
8/00	99.696	99.696	99.696	99.696	99.696	99.696	99.696	99.696
7/50	99.432	99.495	99.440	99.730	99.712			99.494
25	99.335	99.064	98.988	99.717	99.698			99.367
24	99.330	99.050	99.966	99.706	99.704			99.360
23	99.326	99.034	98.937	99.704	99.702			99.344
22	99.325	99.023	98.909	99.702	99.702			99.334
21	99.313	99.011	98.873	99.702	99.699			99.321
20	99.309	99.003	98.859	99.696	99.693	98.837	99.009	99.317
6/80	99.146	98.711	98.525	99.719	99.715			99.167
60	99.056	98.566	98.390	99.715	99.724			99.099
40	98.990	98.424	98.214	99.694	99.703			99.009
20	98.921	98.330	98.086	99.672	99.707			98.949
6/00	98.850	98.215	97.977	99.676	99.686	97.982	98.810	98.888
5/55	98.774	98.084	97.810	99.660	99.662			98.799
54	98.771	98.059	97.806	99.659	99.660			98.796
53	98.777	98.060	97.800	99.657	99.660			98.795
52	98.773	98.059	97.797	99.650	99.662			98.797
51	98.776	98.060	97.790	99.660	99.664			98.796
50	98.773	98.054	97.801	99.662	99.667			98.796
5/00	98.706	97.981	97.716	99.645	99.667	97.719	98.139	98.752
4/80	98.804	97.951	97.680	99.683	99.707			98.755
60	98.805	97.945	97.691	99.659	99.682			98.744
40	98.885	97.986	97.730	99.662	99.714			98.760
20	98.882	97.985	97.761	99.677	99.716			98.765
4/00	98.939	98.013	97.812	99.663	99.693	97.051	98.225	98.799
3/50	99.039	98.085	97.977	99.677	99.694			98.855
05	99.201	98.268	98.233	99.713	99.740			98.979
04	99.194	98.267	98.250	99.717	99.744			98.992
03	99.196	98.266	98.245	99.717	99.740			98.993
02	99.196	98.266	98.243	99.711	99.739			98.990
01	99.196	98.266	98.245	99.710	99.737			98.990
3/00	99.196	98.267	98.246	99.708	99.736	98.266	98.403	99.014
2/80	99.255	98.345	98.357	99.698	99.725			99.031
60	99.329	98.463	98.409	99.735	99.767			99.113
40	99.341	98.503	98.540	99.694	99.721			99.114
20	99.433	98.644	98.690	99.733	99.762			99.207
10	99.443	98.681	98.719	99.747	99.764			99.226
2/00	99.457	98.725	98.747	99.749	99.737	98.720	98.676	99.234
1/80	99.521	98.843	98.870	99.734	99.724			99.293
60	99.567	98.935	98.971	99.772	99.756			99.359
30	99.566	99.130	99.093	99.722	99.695			99.410
20	99.644	99.264	99.159	99.715	99.694			99.456
10	99.703	99.252	99.226	99.741	99.733			99.468
1/00	99.707	99.269	99.274	99.737	99.743	99.271	99.070	99.511
0/80	99.743	99.358	99.313	99.706	99.720			99.525
60	99.769	99.401	99.309	99.715	99.720			99.556
40	99.827	99.505	99.486	99.714	99.724			99.610
20	99.882	99.626	99.610	99.690	99.698			99.654
10	99.929	99.712	99.709	99.726	99.724			99.720
05	99.985	99.733	99.736	99.720	99.716			99.826
04	99.935	99.737	99.738	99.717	99.712			99.726
03	99.932	99.741	99.745	99.716	99.709			99.788
02	99.928	99.745	99.748	99.711	99.706			99.728
01	99.924	99.746	99.753	99.707	99.700			99.729
0/00	99.932	99.756	99.756	99.708	99.698	99.910	99.701	99.727

*Excluding runs 2-NRO and 3-NRO

Table BXII. Track 6, right wheel path.

Station	Level	Profilometer					
		1-NR	2-NR	2-NRR	1-NRR	2-NRO	1-NRO
8/00	99.668	99.668	99.668	99.668	99.668	99.668	99.668
6/00	98.829	98.438	98.065	99.672	99.664	98.181	99.526
5/00	98.754	98.276	97.855	99.671	99.652	9..019	98.378
4/00	98.882	98.276	97.955	99.646	99.636	98.116	98.459
3/01	99.150	98.476	98.305	99.650	99.656	98.452	98.604
2/00	99.420	98.864	98.765	99.690	99.677	98.986	98.859
0/05	99.906	99.744	99.724	99.668	99.653	99.076	99.660

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Table BXIII. Track 7, left wheel path.

Station	Level	Profilometer 3-HR	1-HRR	2-HRR
0/00	99.741	99.741	99.741	99.741
01	99.720	99.733	99.737	99.739
02	99.722	99.734	99.725	99.730
03	99.704	99.720	99.715	99.720
04	99.701	99.715	99.710	99.724
05	99.699	99.703	99.699	99.719
10	99.666	99.660	99.666	99.716
20	99.634	99.617	99.650	99.722
40	99.571	99.562	99.634	99.736
60	99.544	99.539	99.644	99.762
80	99.594	99.508	99.685	99.790
1/00	99.445	99.453	99.642	99.803
10	99.412	99.416	99.633	99.803
20	99.385	99.368	99.607	99.803
40	99.331	99.324	99.588	99.813
60	99.295	99.246	99.562	99.824
80	99.246	99.176	99.565	99.855
2/00	99.209	99.111	99.547	99.846
10	99.192	99.097	99.562	99.861
20	99.163	99.064	99.529	99.844
40	99.137	99.043	99.574	99.860
60	99.095	98.997	99.592	99.342
80	99.022	98.939	99.602	99.846
3/00	98.973	98.869	99.626	99.853
01	98.964	98.861	99.627	99.849
02	98.959	98.856	99.625	99.845
03	98.957	98.846	99.615	99.840
04	98.955	98.846	99.617	99.841
05	98.957	98.849	99.619	99.828
50	98.831	98.701	99.622	99.829
4/00	98.713	98.550	99.624	99.799
20	98.673	98.508	99.609	99.801
40	98.631	98.464	99.650	99.820
60	98.600	98.455	99.635	99.830
80	98.573	98.452	99.636	99.831
5/00	98.554	98.441	99.646	99.811
01	98.553	98.443	99.646	99.807
02	98.555	98.440	99.642	99.816
03	98.549	98.440	99.647	99.815
04	98.552	98.440	99.648	99.810
05	98.555	98.438	99.646	99.806
50	98.513	98.430	99.676	99.773
6/00	98.644	98.560	99.625	99.757
20	98.680	98.626	99.610	99.729
40	98.743	98.713	99.612	99.749
60	98.793	98.790	99.601	99.729
80	98.885	98.885	99.612	99.714
7/00	98.995	99.017	99.647	99.718
01	98.999	99.018	99.647	99.725
02	99.010	99.032	99.644	99.725
03	99.022	99.041	99.647	99.728
04	99.027	99.053	99.650	99.730
05	99.033	99.065	99.656	99.731
50	99.230	99.352	99.698	99.711
8/00	99.440	99.744	99.743	99.741

Table BXIV. Track 7, right wheel path.

Station	Level	Profilometer 3-HR	1-HRR	2-HRR
0/00	99.661	99.661	99.661	99.661
1/00	99.379	99.330	99.653	99.652
2/00	99.192	99.076	99.565	99.705
4/00	98.644	98.632	99.700	99.663
5/00	98.484	98.496	99.661	99.653
6/00	98.576	98.630	99.594	99.646
7/00	99.205	99.397	99.669	99.627
8/00	99.414	99.673	99.669	99.671

Table BXV. Track 8, left wheel path.

Station	Level	Profilometer 5-HR	6-HR	2-HRR	4-HRR
0/00	99.559	99.559	99.559	99.559	99.559
10	99.567	99.428	99.469	99.532	99.551
20	99.605	99.330	99.380	99.534	99.559
30	99.593	99.219	99.284	99.522	99.543
50	99.608	98.998	99.103	99.510	99.522
70	99.535	98.724	98.864	99.554	99.536
90	99.431	98.439	98.600	99.540	99.516
1/00	99.386	98.327	98.495	99.584	99.556
10	99.341	98.197	98.374	99.540	99.510
30	99.479	98.217	98.377	99.494	99.462
50	99.598	98.357	98.499	99.516	99.492
70	99.706	98.485	98.614	99.527	99.520
90	99.743	98.620	98.716	99.570	99.553
2/00	99.785	98.687	98.780	99.568	99.567
10	99.827	98.775	98.865	99.594	99.576
30	99.903	98.961	98.958	99.550	99.539
50	99.961	99.241	99.153	99.584	99.579
67.5	100.023	99.456	99.360	99.563	99.560
70		99.484	99.490	99.563	99.561
75		99.560	99.560	99.559	

Table BXVI. Track 8, right wheel path.

Station	Level	Profilometer 5-HR	6-HR	1-HRR	4-HRR
0/00	99.559	99.559	99.559	99.559	99.559
10	99.567	99.450	99.470	99.540	99.536
20	99.605	99.367	99.407	99.561	99.551
30	99.593	99.268	99.315	99.540	99.521
50	99.608	99.108	99.196	99.573	99.554
70	99.535	98.908	99.043	99.639	99.633
90	99.431	98.638	98.772	99.584	99.579
1/10	99.341	98.463	98.610	99.605	99.595
30	99.479	98.404	98.527	99.457	99.440
50	99.598	98.510	98.619	99.470	99.468
70	99.706	98.643	98.732	99.533	99.513
90	99.743	98.740	98.825	99.575	99.542
2/10	99.827	98.862	98.928	99.565	99.535
30	99.903	99.053	99.078	99.524	99.510
50	99.961	99.313	99.308	99.573	99.547
67.5	100.023	99.489	99.476	99.565	99.556