DEVELOPMENT OF AN AUTOMATIC ELECTROMECHANICAL NULL-SEEKING DEVICE FOR THE PCA ROAD METER

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Success of the original PCA road meter has been largely due to the unique road meter switch plate that allows simplification of statistical calculation of the summation of squared road-car deviations [$\Sigma(D^2)$]. The idea, equipment, and procedures involved in the development of the road meter are given elsewhere (1).

The paper disclosed that the number and magnitude of road-car deviations are distributed in a plus-minus array so that $\Sigma(D)$ is practically zero or so small that $\Sigma(D^2)$ can be calculated with minimum effort and complication. However, the method depends on ability to maintain initial static null reference between roller contactor and null segment of the switch plate after the test begins and the road meter car is in a dynamic state.

During the test, the original static null can be changed by a number of events. These are (a) error in the initial adjustment itself, (b) change in position and weight of car load, (c) excessive braking or acceleration, and, most important, (d) lifting of the car body (deviation datum) by aerodynamic forces created by car speed and ambient wind velocity and direction relative to car travel.

Any or all of these changes can take place during a single test. Each change or condition results in recordings of digital counter data peculiar to the existing condition. Therefore, the composite data are a combination of groups of high-frequency road roughness recordings, each separated in the switch plate by extraneous movement or translation not associated with pavement roughness. Use of composite data, no matter how measured and recorded, will result in a $\Sigma(D^2)$ statistic that is always greater than $\Sigma(D^2)$ attributable to road roughness alone.

A solution to the problem is to have a mechanism attached to the road meter that is capable of sensing extraneous inputs that change static null, correct for these in amount and direction, and thus ensure digital counter recordings that are a result of road roughness alone. This paper presents a discussion of the problem and describes an inexpensive device capable of accomplishing the solution.

PRACTICAL EFFECT OF NULL SHIFT DURING TEST

Shifting of the road roughness spectrum can be caused by a number of events during a single test. Some, such as passenger movement, may be of short duration, and others may be of long duration and varied as in the case of ambient wind velocity and direction relative to car travel.

To illustrate the effects of null shift, we have constructed a hypothetical example (Table 1). Counter recordings are listed for a 1-mile section of road, where these recordings represent true road-car deviations without extraneous effect. On a hypothetical rerun of the 1-mile section, ½ mile was accomplished without extraneous effect. The remaining ½ mile, included in the single test, was affected by high side wind so that null adjustment was shifted ²⁄₈ in.

Table 1. Hypothetical example of effect of null shift during test.

	Perfect Null		Null Shift ($^2/_8$ in.)	Composite*		
Road-Car Deviation ($^1/_8$ in.)	Counter Recording (1 mile)	Counter Recording ($^1/_2$ mile)	Counter Recording ($^1/_2$ mile)	Counter Recording (1 mile)	Shift Deviation Base	Σ-counts
-4	0	0	0	0	-5	0
-3	6	3	0	3	-4	12
-2	42	21	0	21	-3	63
-1	152	76	3	79	-2	158
0	232	116	21	137	-1	137
+1	152	76	76	152	0	0
+2	42	21	116	137	+1	137
+3	6	3	76	79	+2	158
+4	0	0	21	21	+3	63
+5	0	0	3	3	+4	12
Σ-counts per mile	508	508	1,276	892	-	740
PSI	4.30	4.30	3.44	3.75	-	3.93

*The data in this column are derived from the preceding 2 columns.

Figure 1. Diagram of electrical equipment for automatic null adjustment of PCA road meter.

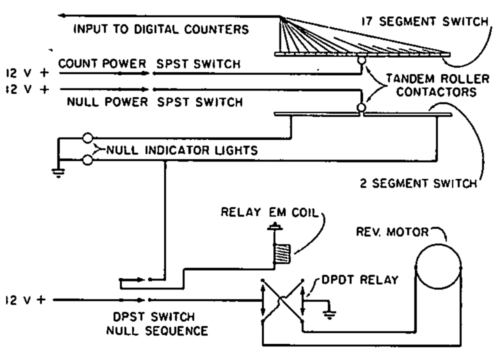

Figure 2. Connections between reversible motor and switch plate.

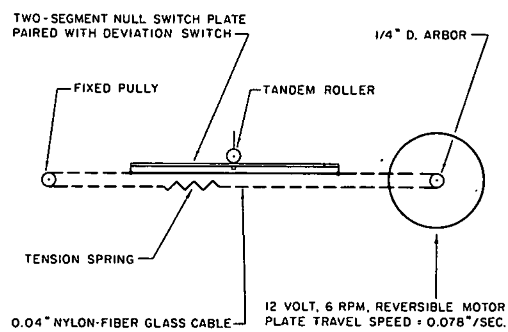

Table 2. Effectiveness of automatic null-seeking device attached to PCA road meter.

Road-Car Deviation ($^1/_8$ in.)	Static Null (southerly wind, 10 mph) Count Record	Automatic Null (westerly wind, 28 mph) Count Record	Static Null (westerly wind, 28 mph) Count Record
1	532	409	332
2	270	280	328
3	79	92	211
4	20	26	98
5	4	4	31
6	1	0	8
7	0	0	3
Σ-counts	1,415	1,458	2,237
PSI	3.36	3.33	2.98

According to Table 1, the full mile has a true PSI of 4.30 when measured without extraneous effect. The first ½ mile, measured in the rerun without extraneous effect, also shows a PSI of 4.30. The second ½ mile, run with extraneous effect amounting to null-shift of ²⁄₈ in., shows a PSI of 3.44. Composite 1-mile data for the rerun give a PSI of 3.75. In each case computations have been made on the assumption that the road meter remained in perfect static null.

Had the operator known that a shift had taken place, he might view the data from digital counters and conclude that the frequency curve was symmetrical but shifted +⅛ in. He might then shift the measurement scale by ⅛ in. and compute Σ-counts. PSI then comes out at 3.93, still less than the true value without extraneous influence.

SOLUTION OF THE NULL-SHIFT PROBLEM

Road-car deviation inputs to digital counters in a PCA road meter are very rapid. On the average, time for a complete plus or minus deviation should not exceed about 0.3 sec and could be as short as 0.025 sec at the maximum capacity of the counter itself. Therefore, the duration of a single plus or minus excursion of the roller contactor from the null switch plate segment is very limited; and when perfectly nulled, the contactor will spend about as much time on one side as the other during a lengthy test.

If an extraneous influence is introduced and continued during a test, the contactor will move off null, but it will still maintain the centrally oriented rapid movements induced by road roughness input. Then the contactor will spend more time on one side of static null than the other. Correction of the off-null position can be achieved by a time-sensing device that makes automatic correction by shifting the switch plate to a new position that will tend to equalize plus and minus excursion times.

Within-test adjustment of the switch plate can be done mechanically by use of a reversible motor actuated by a separate roller contactor and 2-segment switch plate exactly paired with the roughness deviation plate. Pairing means that the division in the 2-segment plate is exactly adjacent to the center of the null segment of the deviation plate and that the motor roller contactor is exactly adjacent to the deviation roller where both operate in unison according to relative road-car movement.

The general position of deviation and motor switches, roller contactors, and electrical requirements is shown in Figure 1. Figure 2 shows the connections between reversible motor and combined switch plate.

Figure 1 shows that the position of the contactor on the 2-segment switch plate will activate a DPDT relay that will decide the direction of rotation of the motor and direction of travel of the combined switch plate. By selection of proper polarity in wiring, the relay will direct plate movement always toward a perfect null.

It is obvious that very fast correctional movement of the switch plate might override roller movements related to roughness alone. However, motor rotation is geared down, and by use of the indicated motor speed and reduction arbor, plate travel has been reduced to only 0.078 in. per sec. If a plus or minus deviation requires 0.3 sec for completion, the maximum attenuation possible is only 0.023 in.

In spite of the slow plate movement, the very rapid reversals of direction will quickly compensate for extraneous effects creating a faulty null. The predominant movement of the plate will be automatically controlled by the relative time that the motor roller contactor spends on one side or the other of its own 2-segment switch plate. Experience has shown that these corrections for extraneous influence will be made in 2 or 3 sec and that perfect null will be achieved. If extraneous conditions change, corrections are automatically applied.

USE OF THE AUTOMATIC NULL DEVICE

The automatic null device was developed by the author in early 1971. It has been in use in numerous road and airport surveys, and tests have been conducted to verify its effectiveness. One example is given in Table 2, where tests in a single site were influenced by high wind velocity. In this case, the survey car was operated southbound into a tolerable 10-mph head wind, and a PSI of 3.36 was recorded. On the following day, wind had increased to 28 mph, and direction was at right angle to car movement. With static null, wind effects reduced PSI to 2.98, and count recordings were questionable because of the unlikely array displayed by counters 1, 2, and 3. Immediate rerun with the automatic null in operation gave results that correspond to those of the previous day.

Other observations indicate that within-test variability will be reduced substantially, probably in the order of 50 percent. The Wisconsin Division of Highways has reported great improvement in repeatability, reduction in downtime due to wind restrictions, and increased safety in the operation of road meter vehicles because static null adjustment is not required.

CONCLUSION

Development of the automatic, null-seeking device should increase the reliability of the PCA road meter, improve efficiency and safety, and reduce mass inventory costs.

REFERENCE

1. Brokaw, M. P. Development of the PCA Road Meter: A Rapid Method for Measuring Slope Variance. Highway Research Record 189, 1967, pp. 137-149.