A CANADIAN EVALUATION STUDY OF ROAD METERS

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Road construction and maintenance activities may be considered as a service provided to the motoring public. The level of service extended is a function of the pavement's characteristics and properties. One variable having considerable influence is the riding quality of the pavement, i. e., the roughness of ride produced by the pavement surface. Methods must be available to measure this property in order to establish the level of service on a quantitative basis and to determine the cost-effectiveness of funds invested in pavement maintenance and rehabilitation.

A number of methods have been developed to measure pavement riding quality or roughness, but the cost and other characteristics of these methods often limit their use to special studies or to the testing of representative sections. A need exists for a low-cost, rapid method that can produce reliable and consistent measurements for the mass inventory of extensive road networks.

The road meter is a promising development toward fulfilling this need. The device is relatively inexpensive, and its speed of operation allows roughness measurements to be taken on several miles of highway in a day. This report concerns a study carried out by the Pavement Management Committee of the Roads and Transportation Association of Canada (RTAC) to investigate the reliability and consistency of road meter measurements.

ROAD METER EVALUATION STUDY

Objectives

The road meter evaluation study made by the Pavement Management Committee of RTAC was carried out during the summer of 1970. Several members of the committee had acquired one or more road meters; these meters often differed from the standard model (1, 2) and from each other. Differences were commonly found in the number of counters installed on the meter, and one agency (3) had made extensive electronic modifications to the basic road meter design. Moreover, these meters were installed in vehicles of various makes and models having substantial differences in suspension characteristics. Consequently, a prime objective of the evaluation study was to compare the measurements of these different meters and to determine the extent to which variations in meter design affected accuracy and reliability of measurements.

A second objective of the evaluation study was to correlate road meter Σ-counts with subjective ratings. Riding comfort index (RCI) is the standard measure of pavement riding quality recommended by RTAC (4, 5), and over the years Canadian agencies have developed considerable data and experience in terms of this measure. It was, therefore, considered that road meters would not receive general acceptance unless RCI's could be predicted with reasonable accuracy from road meter Σ-counts. RCI is similar to the present serviceability rating (PSR) widely used in the United States, except that RCI is established from subjective ratings made on a scale of 0 to 10, whereas PSR is established on a scale of 0 to 5.

A further objective of the study was to investigate the effect of testing speed and to establish whether an optimum testing speed existed that would minimize the error in relating road meter Σ-counts to RCI.

Testing Program

The investigations carried out actually consisted of 4 studies in which several types of road meters were used. The road meter common to all 4 studies was owned by the Canadian Department of Transport. This road meter was used at various airports and was compared with the meters of other agencies.

The first and most extensive of the 4 studies was carried out on 30 road sections in Quebec. Measurements were made on these sections with 4 road meters belonging to the Department of Highways of Quebec, by a road meter owned by the Department of Highways of Ontario, and by the Department of Transport road meter. The 4 Quebec meters tested the sections at 30 and 40 mph, and the Ontario and Transport meters ran measurements at 40 and 50 mph. RCI's of the Quebec test sections were established with a 9-man panel, except for 6 of the sections that were rated by only 3 persons.

A second study was conducted in Manitoba, where road meters of the Department of Transport and the Manitoba Department of Public Works were used on 30 test sections at 50 mph. RCI's were not determined for the Manitoba test sections.

A third study was conducted in Alberta, where the Research Council of Alberta established a set of 38 test sections to calibrate measurements by its road meter in terms of RCI. They conducted road meter measurements on these sections at 30, 40, and 50 mph and established RCI's with a 3-man panel. Twenty-eight of the Alberta test sections were also tested with the Transport road meter at 50 mph.

The fourth study was carried out in British Columbia, where 34 sections were tested by the Transport road meter and were rated by a panel from the Department of Highways of British Columbia. The rating panel consisted of 12 men, each of whom rated the sections on 3 separate occasions while seated in a different place within the test vehicle. The ratings obtained for the British Columbia test sections thus represented the mean opinion of a large-sized panel.

RESULTS OF EVALUATION STUDIES

Variation in Road Meter Measurements

The evaluation studies, involving 8 road meters, demonstrated that different road meters do not necessarily give the same Σ-values. Figure 1 shows the average relations between Σ-counts produced by the Department of Transport road meter and Σ-counts produced by each of the other 7 meters. Some of the other meters gave Σ-counts quite similar to those of the Transport meter, whereas other meters gave Σ-counts that were substantially different. As an extreme example, Figure 2 shows a comparison of the 40-mph measurements on the Quebec test sections by Quebec meters 3 and 4. The Σ-counts produced by Quebec meter 3 were approximately twice those produced by Quebec meter 4. Consequently, it cannot be assumed that 2 different meters will give similar Σ-counts. A comparison of results from 2 different meters requires that a correlation be established between their measurements.

Although measurement may not be numerically similar, the road meter evaluation studies indicated that a good linear correlation existed between any 2 meters. Table 1 gives the results of regression analyses between Σ-counts by the Department of Transport road meter and Σ-counts produced by the other road meters. The coefficient of correlation in these relations is 0.94 or better.

The ability to correlate the measurements of 2 road meters with a good degree of accuracy suggests that details concerning the construction of road meters are not highly significant in achieving consistent measurements. The Ontario and Manitoba meters had 8 counters, the 4 Quebec meters had 11 counters, the Transport meter had 12 counters, and the Alberta meter had the equivalent of 16 counters along with extensive electronic modifications. The Alberta road meter actually has only 8 counters, but the equivalent of 16 counters is produced by an extended switch plate and a double pole

Figure 1. Comparison of Transport road meter with other road meters.

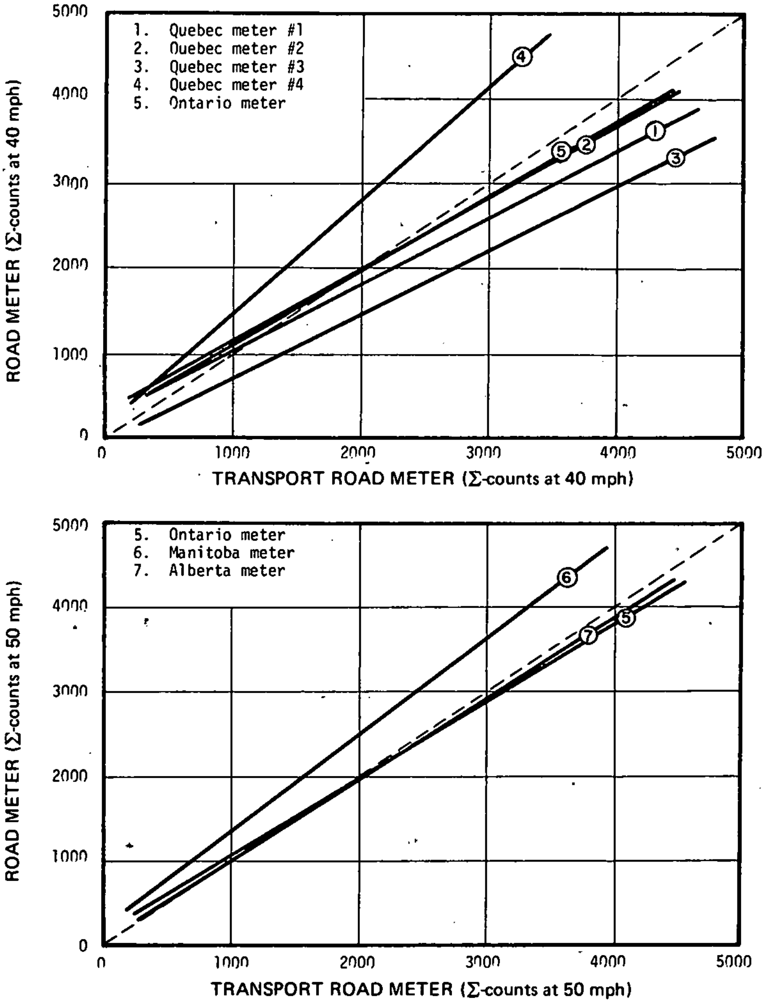
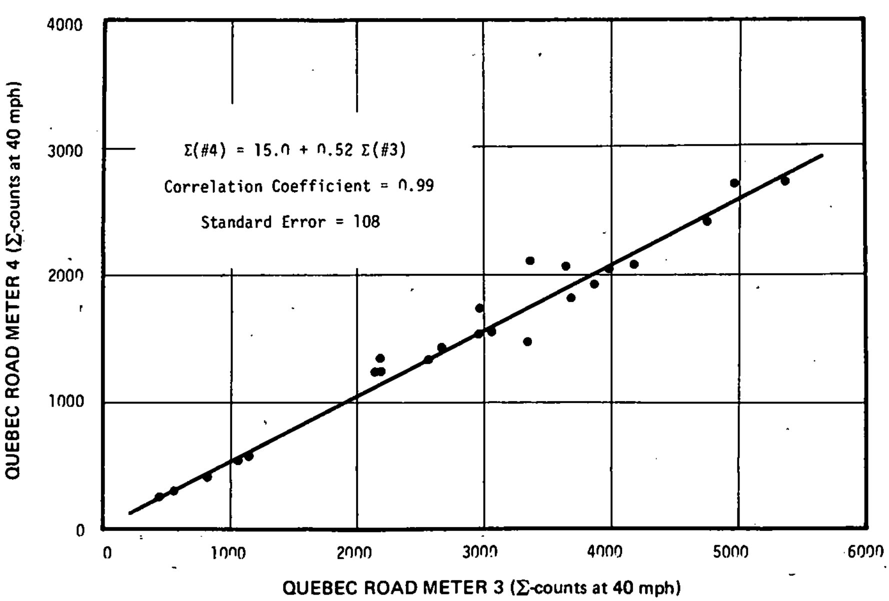


Figure 2. Comparison of Quebec road meters 3 and 4.



switch to change the counters from a low to high range during a second test run. In addition to these construction differences, various types and models of automobiles were employed as test vehicles. Despite all these variations, the coefficients of correlation between Σ-counts by different road meters ranged from 0.94 to 0.98. It would thus appear that the standard 8-counter road meter available from commercial sources is adequate for general use. Additional counters may be desirable for the testing of rougher pavements because they give more information on the larger car-axle movements.

Road Meter Ratings Versus Subjective Ratings

The road meter evaluation studies generated a number of correlations between RCI and road meter Σ-counts measured at various testing speeds. A summary of these correlations is given in Table 2. Figure 3 shows the correlations between RCI and Transport road meter Σ-counts for the Quebec, Alberta, and British Columbia test sections.

The degree with which road meter measurements relate to RCI may be judged from the standard error in predicting RCI from Σ-counts. As given in Table 2, these standard errors were rather high for the Quebec and Alberta test sections, where the ratings were established by panels ranging in size from 3 to 9 men. The magnitude of these standard errors would suggest that road meter measurements do not predict RCI with a high degree of accuracy. With the British Columbia sections, however, where the ratings represent the average opinion of a large-sized panel, the standard error in predicting RCI from Σ- values was 0.39 RCI unit. Although not conclusive, this figure indicates that RCI can be estimated from Σ-counts with reasonable accuracy and that the larger errors associated with the Quebec and Alberta data are possibly due to the smaller size of rating panels.

Another variable that may influence RCI and Σ-counts correlation is panel bias. This effect is noticeable in Figure 3, where the individual regression relations between RCI and Transport road meter Σ-counts are shown separately for the Quebec, Alberta, and British Columbia data. The curves for the Quebec and British Columbia data almost coincide, indicating that these 2 panels rated pavements in much the same manner. The regression curve for the Alberta data indicates that the Alberta panel, on the average, rated pavements 1.0 to 1.5 RCI units more severely than the other 2 panels.

The results illustrate some of the difficulties inherent in establishing accurate and reproducible calibrations for road meter Σ-counts in terms of subjective ratings. To promote accuracy and reproducibility, we must consider carefully the manner in which calibrating tests are carried out. It is suggested that calibrating test sections should be at least ½ mile in length, of uniform roughness throughout the section, and situated on level, tangent alignments. An adequate sample of sections would possibly number 30 or more, with surfaces ranging from smooth to rough. Better correlations with smaller standard errors are likely to result if a large rating panel is employed, and the panel members should be fairly representative of the general population in order to avoid biases.

Road Meter Testing Speed

Road meter measurements are influenced to various degrees by a number of variables. One variable having a significant effect is vehicle test speed, as shown in Figure 4, where Σ-counts measured at 50 mph are compared to values obtained on the same sections by the same vehicle traveling at 40 and 60 mph. One objective of the evaluation trials was to obtain some indication of the best vehicle speed at which to take measurements.

Two factors must be considered in deciding on testing speed. One consideration is safety and a requirement for compatibility with normal traffic speeds. The other factor is the effect that testing speed has on the error in predicting RCI from Σ-counts. The data given in Table 2 indicate a slight trend to smaller standard errors in relating RCI to Σ-counts when the Σ-counts are measured at 40 to 50 mph rather than at 30 mph. No significant difference is apparent in the error for testing speeds of 40 and 50 mph. A road meter testing speed of 50 mph would therefore seem most appropriate for normal highway operations.

Table 1. Average relation between Σ-counts of Transport road meter and other road meters.

Testing Speed (mph)	Type of Meter	A	B	Correlation Coefficient
40	Quebec 1	297	0.776	0.94
	Quebec 2	331	0.815	0.94
	Quebec 3	-30	0.752	0.96
	Quebec 4	114	1.342	0.95
	Ontario	211	0.879	0.95
50	Ontario	185	0.905	0.95
	Manitoba	233	1.137	0.95
	Alberta	25	0.949	0.98

Note: $\Sigma_T = A + B\,\Sigma_X$, where Σ_T = Σ-counts by Transport meter and Σ_X = Σ-counts by other meters.

Table 2. Summary of RCI versus Σ-counts regression analyses.

Test Section	Type of Meter	Testing Speed (mph)	A	B	Standard Error
Quebec	Quebec 1	30	15.8	-3.21	0.83
		40	17.6	-3.63	0.82
	Quebec 2	30	16.8	-3.54	0.82
		40	17.4	-3.61	0.81
	Quebec 3	30	18.2	-3.78	0.49
		40	18.0	-3.62	0.52
	Quebec 4	30	19.1	-4.52	0.78
		40	18.2	-4.02	0.75
	Ontario	40	17.3	-3.57	0.77
		50	18.1	-3.70	0.85
	Transport	40	17.9	-3.76	0.84
		50	19.5	-4.11	0.84
Alberta	Alberta	30	19.4	-4.71	0.96
		40	19.7	-4.68	0.88
		50	21.1	-4.98	0.87
	Transport	50	19.8	-4.63	0.90
British Columbia	Transport	50	19.3	-4.01	0.39

Note: RCI = A + B log (Σ).

Figure 3. Relation between RCI and Transport road meter measurements.

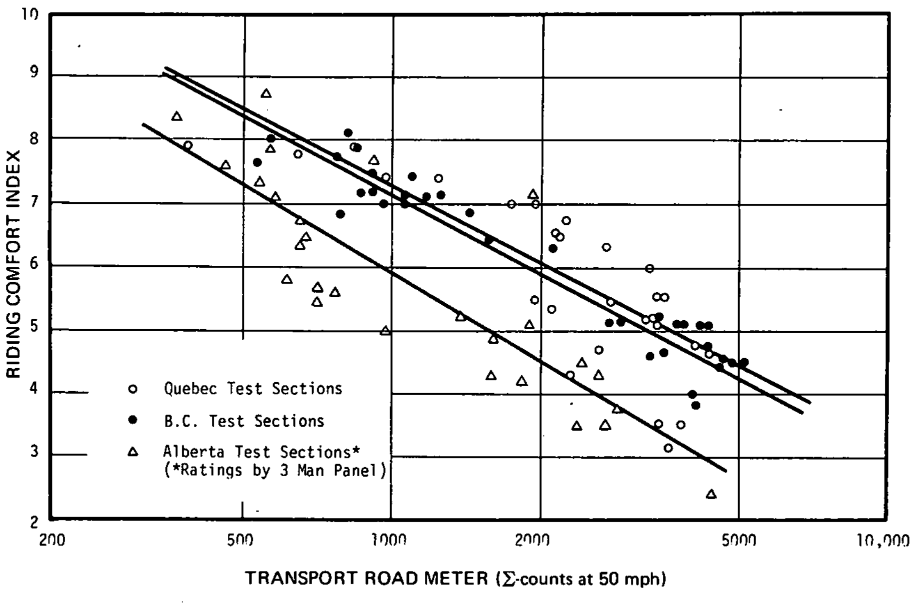


Figure 4. Comparison of road meter measurements at different test speeds.

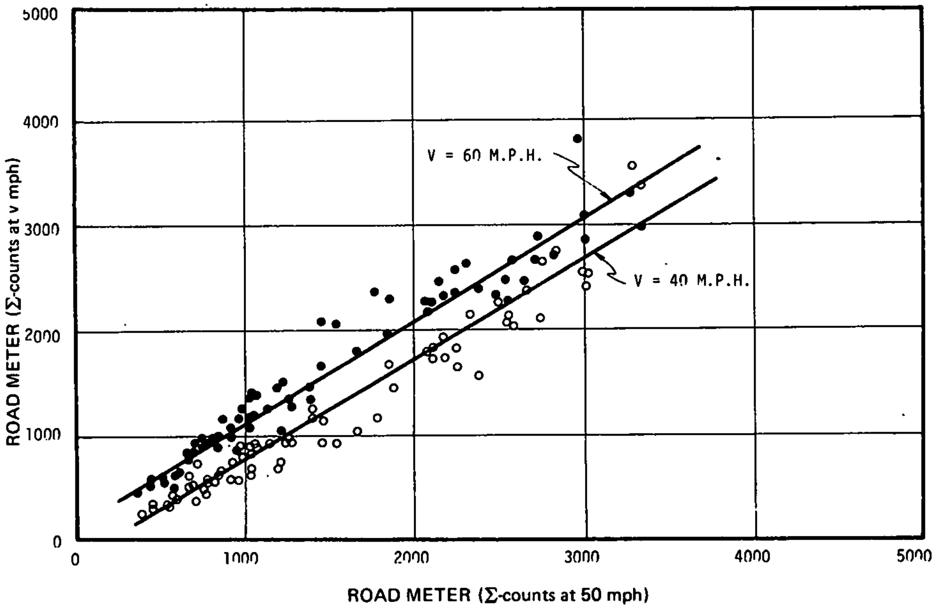
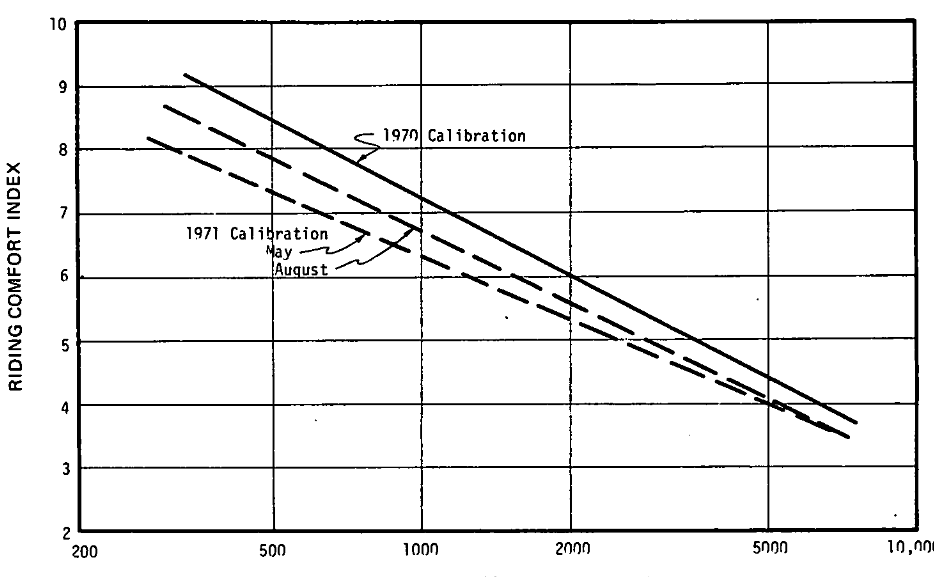


Figure 5. 1970 and 1971 calibrations of Transport road meter.



APPLICATION OF ROAD METER MEASUREMENTS

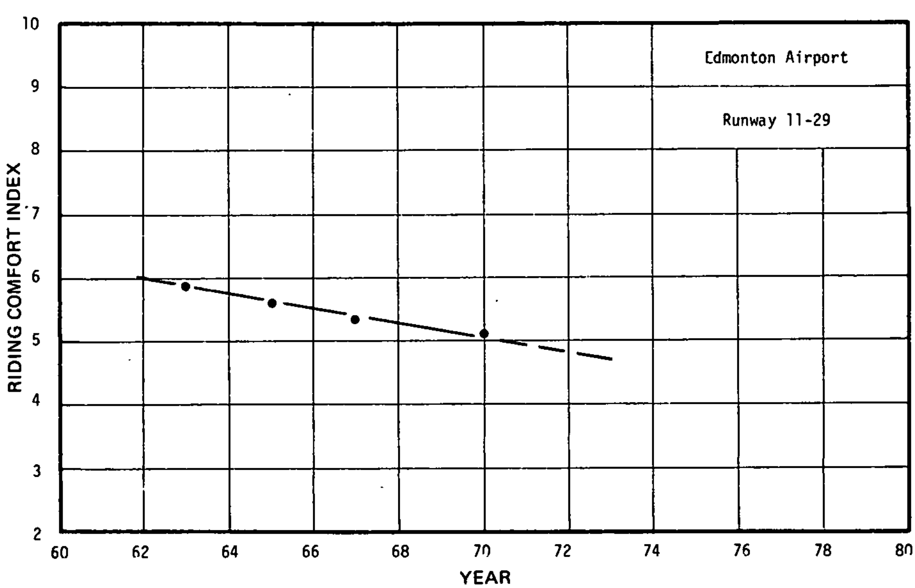
The possible lack of numerical similarity in Σ-counts produced by different meters constitutes one of the main deficiencies of the road meter as a roughness measuring device. Agencies using more than one meter in an inventory program will find it necessary to calibrate the individual meters in terms of a standard meter or some other standard measurement such as RCI. It may also be possible that measurements by a given road meter will change with time because of wear in the meter's components or changes in the suspension system of the test vehicle. To avoid errors of this nature, a set of calibrating test sections should be established so that a meter's calibration can be checked periodically.

An example of change in the measurements by a road meter is shown in Figure 5; the figure shows the calibration curves used for the Department of Transport's meter in 1970 and 1971. Prior to commencing the 1971 testing program, a new set of shocks was installed on the test vehicle. When checking the meter's calibration afterward, it quickly became evident that the new shocks had substantially reduced the Σ-counts produced by the meter. The extent of this change is reflected in the difference between the 1970 and 1971 calibration curves (Fig. 5). The meter's calibration was again checked on completion of the 1971 testing program in which the test vehicle traveled about 12,000 miles. The calibration had again changed to a limited extent.

The evaluation studies have indicated that measurements by a road meter can be relied on to at least classify the roughness, or the riding qualities, of a pavement in the correct order of magnitude. Because of the problems that occur in establishing and maintaining a calibration for the device, it might be questioned whether the road meter in its present state of development will give measurements that can be reproduced with good accuracy over a period of years. The utility of the road meter, therefore, depends on the intended application of its measurements.

An agency, for example, might be interested in conducting a condition survey of its highway network to determine where maintenance and rehabilitation funds could be spent with maximum effect. For a relatively small expenditure, a road meter would provide valuable and significant information in a survey of this nature. Another application of roughness measurements is in the construction of roughness performance charts such as shown in Figure 6. These charts are simply a plot of roughness measurements taken in different years so that one may record the gradual accumulation of roughness in a pavement over its life span. The variation likely to be encountered in

Figure 6. Pavement roughness performance chart.



road meter measurements over a period of years may be of sufficient magnitude to severely limit the usefulness of performance charts.

SUMMARY AND CONCLUSIONS

The following conclusions were derived from the road meter evaluation studies:

1. The assumption cannot be made that 2 road meters will produce measurements of the same numerical value; however, a good linear correlation should exist between these measurements.
2. A reasonable correlation should result between road meter measurements and subjective ratings when these ratings are established by a large, representative panel.
3. Details concerning the construction of road meters and the vehicles in which they are mounted do not seem highly significant in the reliability and consistency of measurements. The standard road meter model with 8 counters is sufficiently accurate for general use although additional counters may be desirable for more detailed information in the testing of rough pavements.
4. Road meter measurements vary with testing speed, and a standard testing speed of 50 mph is appropriate for normal highway applications.
5. Difficulties exist in establishing and maintaining an accurate calibration for a road meter. A set of calibrating test sections is necessary to periodically check the reproducibility of measurements by a meter.

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