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16. ABSTRACT

One of the primary purposes in building a highway is to provide a vehicle path which is more smooth and uniform than the original ground. As a consequence highway engineers have placed considerable emphasis on the surface smoothness of the roadway and from time to time have devised equipment to measure and evaluate pavement roughness.

One of the first of these devices was an instrument known as the vialog developed by the New York State Highway Department which was mounted in a car and actuated by the vertical oscillations of the front axle as the car is driven over the road. A modification of this apparatus is still in use in California and is generally known as a roughometer or "bumpometer."

The roughometer device on a car indicates pavement roughness by summarizing on mechanical counters the vertical movements of the front axle of the car and hence the final totalized values do not differentiate between a number of movements of small amplitude as compared to fewer bumps of greater size. In other words while some idea of total roughness may be gained it is impossible to identify the kind or variety of roughness.

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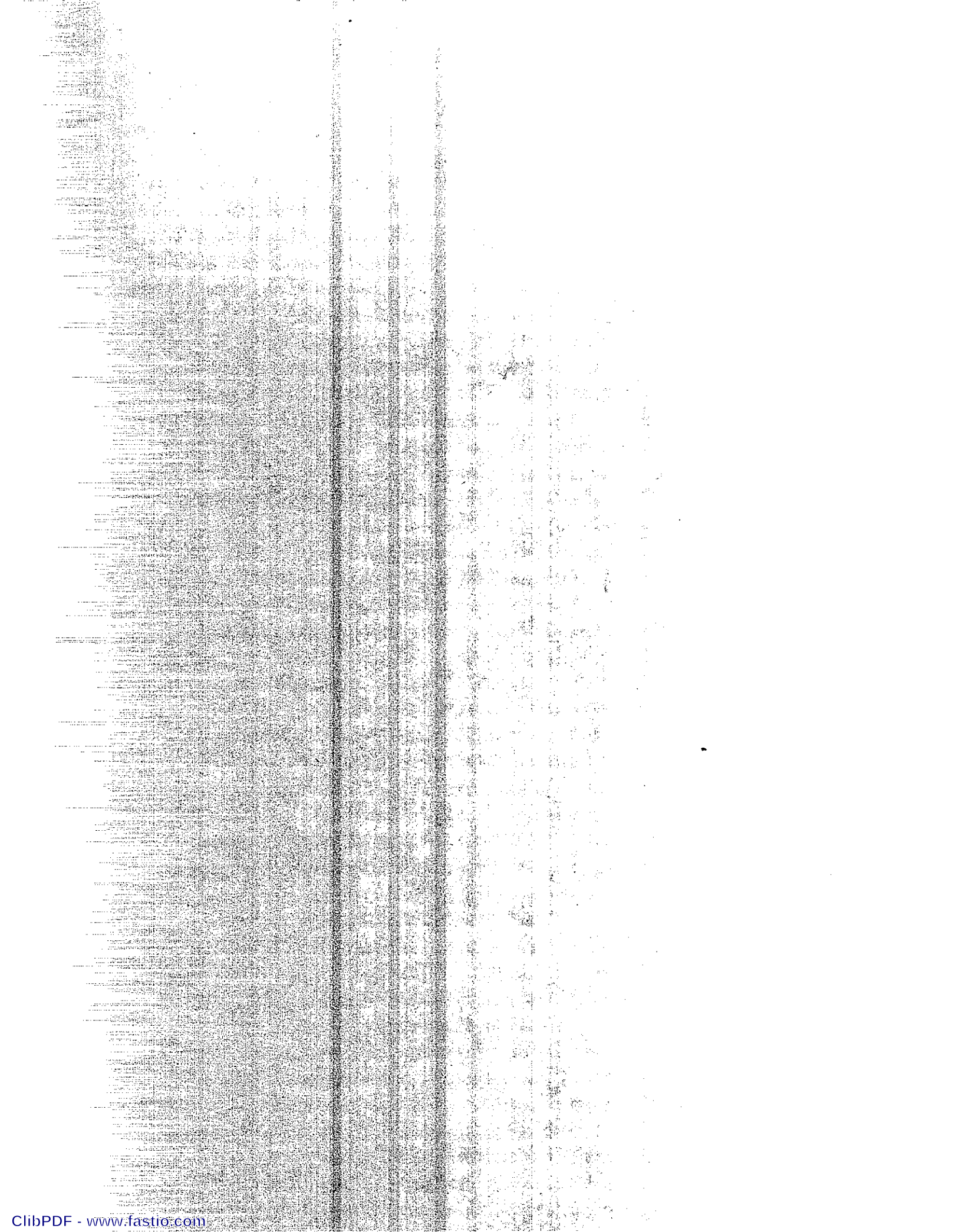

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

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THE LABORATORY BUILDS A PROFILOGRAPH TO MEASURE AND ANALYZE PAVEMENT ROUGHNESS

By F. N. HVEEM*
SENIOR PHYSICAL TESTING ENGINEER

MAY, 1944

ONE of the primary purposes in building a highway is to provide a vehicle path which is more smooth and uniform than the original ground. As a consequence highway engineers have placed considerable emphasis on the surface smoothness of the roadway and from time to time have devised equipment to measure and evaluate pavement roughness.

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* Mr. F. N. Hveem, the writer of this article is also the designer of the new profilograph machine built by the Materials and Research Department of the Division of Highways, for measuring the roughness of highway pavements.

PREVIOUS DEFICIENCIES OVERCOME

In order to study highway pavements and to correctly understand the variations in pavement contours due to the effects of traffic, moisture and temperatures, it is necessary to develop a profile on paper which will enable the engineer to visualize not only the magnitude and frequency of pavement inequalities as they affect motor vehicles, but the approximate shape or contour as well. Several devices of this sort have been constructed. One, described in a report of the Road Research Board in Great Britain in 1936, pictures a device with a series of 16 wheels connected by an intricate tubular frame. The entire apparatus appears to have an overall length of some 25 feet.

It is also reported that following the first World War the State of Wisconsin constructed a somewhat similar apparatus using a large number of bicycle wheels. California Highways for December, 1939, carried an article describing a viagraph constructed in District VII and designed in the Los Angeles County Road Department by Mr. C. F. Galloway.

NOT MOUNTED ON AUTO

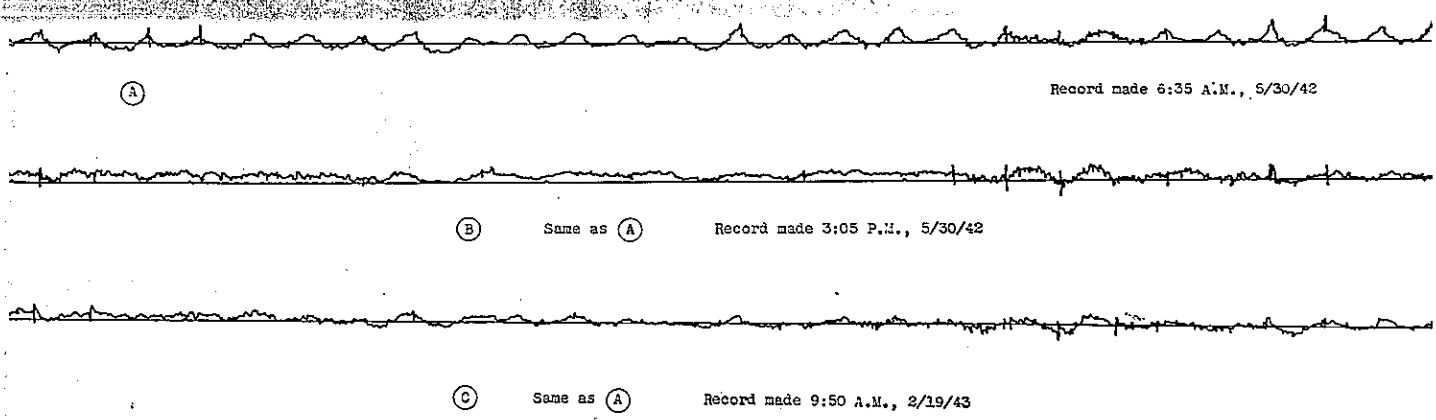
Most of the units thus far constructed seem to have certain disadvantages which may be analyzed as follows: An instrument mounted in an automobile actuated by movements of the car axle does not reflect pavement contour truly, but is a composite value depending on the spring suspension and riding characteristics of the individual car.

The elaborate multiple wheel units such as used in England are very cumbersome and would be difficult to transport for long distances. The type of apparatus using only three wheels does not produce a true profile record as many pavement inequalities are canceled out, others are amplified or multiplied in number.

In designing a profilograph for use by the Materials and Research Department in California an attempt was made to satisfy the following conditions or requirements:

REQUIREMENTS FULFILLED

1. The instrument should have a length or "wheel base" approximately the same as a typical automobile in order that the pavement roughness should be recorded with reference to a motor vehicle plane and not with reference to a continuous plane.



Facsimiles of profilograph records taken on a new pavement under different temperature and weather conditions

2. The instrument should be supported by a multiplicity of wheels, at least 16, mounted on compensating axles in order to provide a datum plane of about the wheel base of an average car parallel to the local pavement contour but which would be virtually independent of minor inequalities.

3. The equipment should be collapsible and capable of quick assembly and, when collapsed, should be compact enough to permit transportation in an ordinary sedan car.

4. Preferably, the instrument should not require special paper with either rulings or perforations. Such paper is expensive and if plain paper rolls similar to that used in commercial adding machines could be utilized a considerable saving would result.

CONTROLLED BY OPERATOR

5. The operator should be in a position to observe the graph at all times during the process of recording and the recorder should be available for remarks or notation on the paper strip.

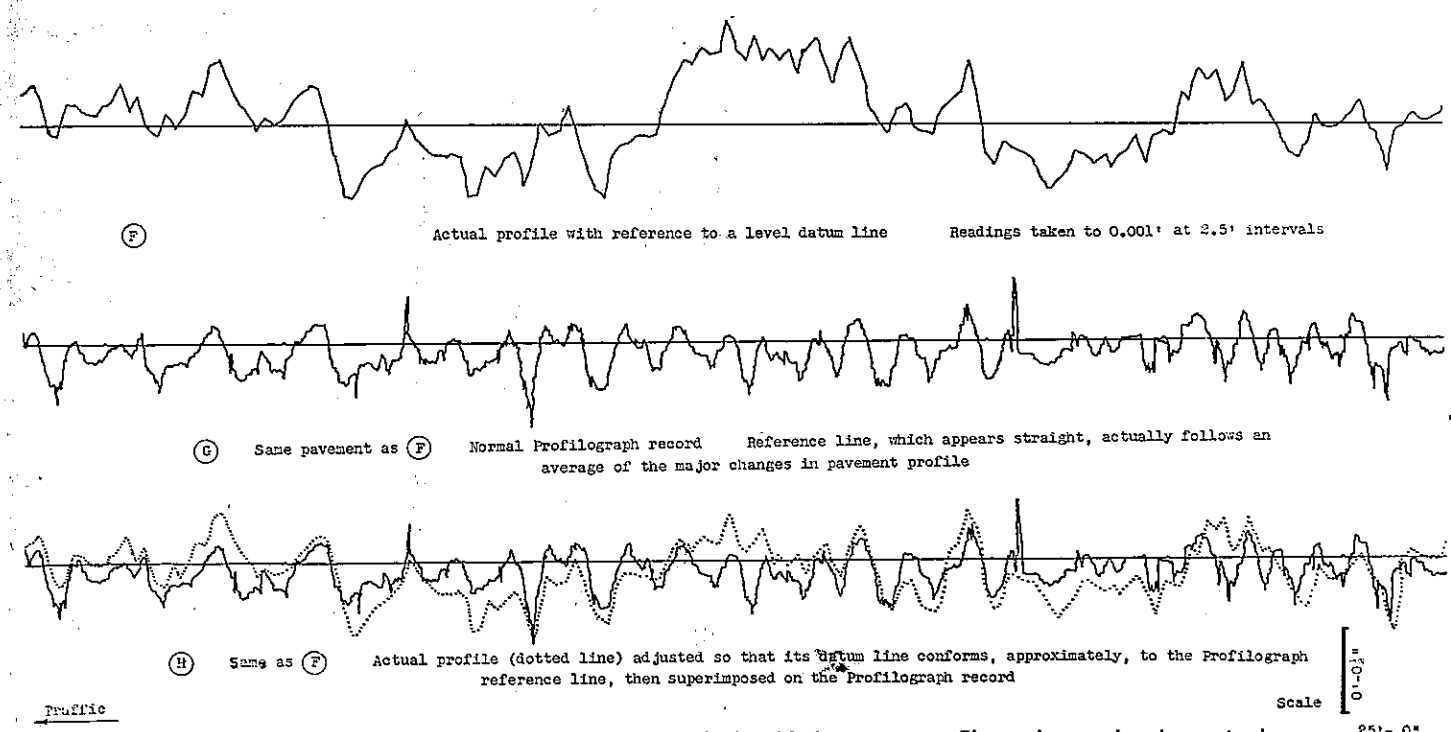
6. The operator should be able to steer the profilograph in order to select and follow a predetermined path.

7. The frame should be very rigid and free from any tendency to sag or "spring" while in operation.

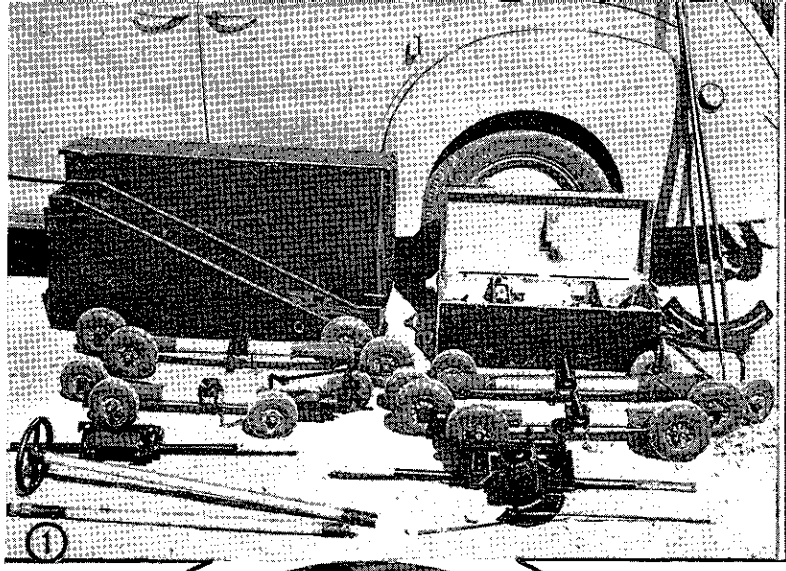
Accompanying sketches and photographs indicate the manner in which these conditions are satisfied. Sixteen small pneumatic-tired wheels were provided, each of which is free to move independently in a vertical plane. These carrier wheels are fixed in a staggered arrangement in order that no two wheels will strike a transverse ridge or inequality (such as an expansion joint), at the same time.

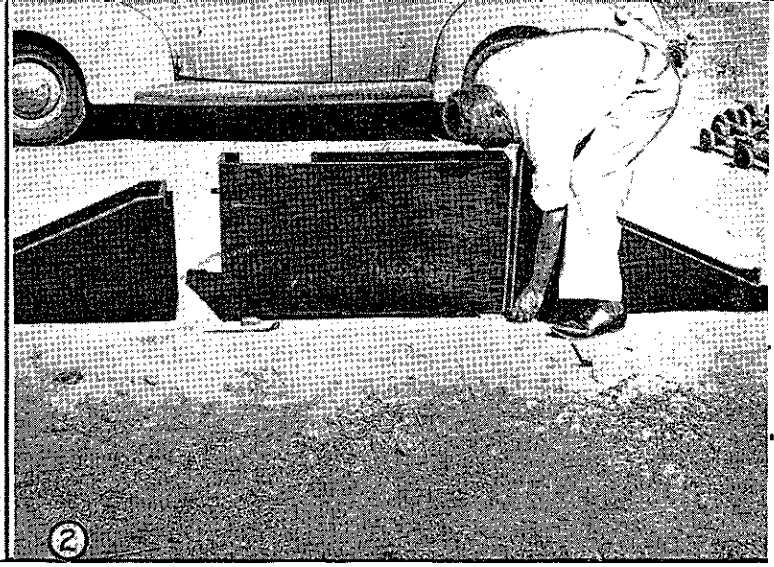
PORTABLE APPARATUS

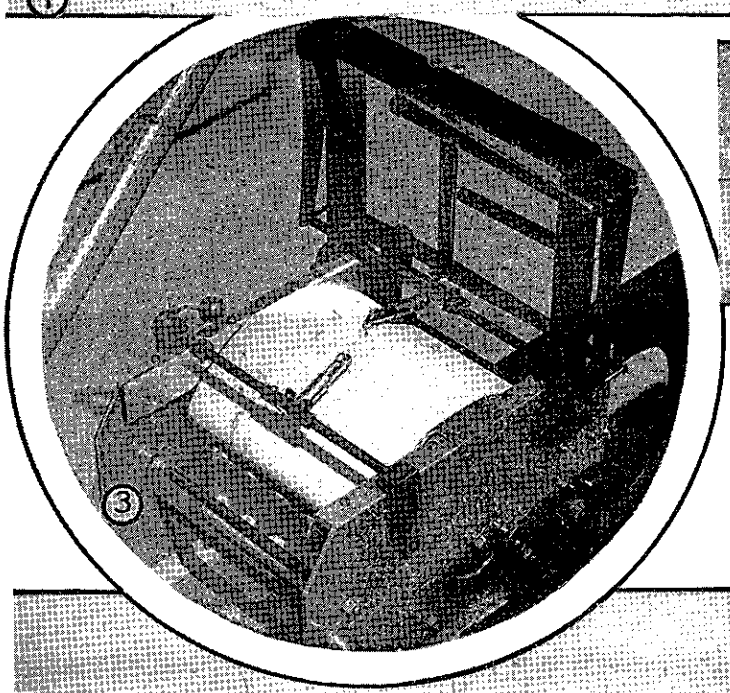
The apparatus may be dismantled into units not over 40" in length and the entire assembly readily stowed in the trunk and tonneau of a small sedan. The instrument as constructed permits changing of the horizontal scale of the recorded graph to either of the following: 1" = 50', 1" = 25'.

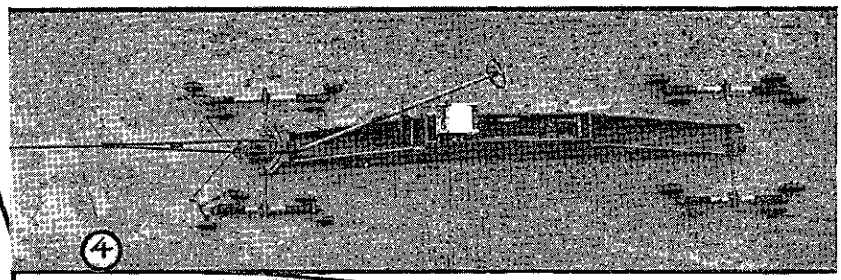


Facsimile records "F," "G" and "H" illustrate the relationship between a profilograph record and an actual profile platted from level notes









The vertical scale may be either 1″ = ½″ or 1″ = 1″. The examples of pavement profiles illustrated herewith were recorded to the scale 1″ horizontal = 25′, 1″ vertical = ½″, and have been reduced to one-half of the original size.

Operation of the profilograph involves the following steps after arriving on the job. First, assembling the machine, second, checking air pressure in the bicycle tire, third, the recording device is installed and pens are filled with ink and adjusted. One pen records the vertical movement of the bicycle wheel with reference to the main carrier frame, the second is adjusted to provide a datum line as a basis for judging the relative deviation of the recorded profile.

TWO PENS USED

The datum pen is actuated by an interrupter which registers a small break in the line at 50 or 100-foot intervals depending on the horizontal scale gear ratio being used. This arrangement of the pens makes it unnecessary for the paper strip to be precisely true or uniform as the two pens will maintain their relative position irrespective of slight lateral movements or shifts on the part of the paper strip.

The paper is fed or controlled by two hard rubber rolls and provides a very uniform and dependable horizontal scale without the necessity for special paper having perforations for a sprocket drive. The recording pen is mounted on a small rod supported by flexible bronze reeds. This construction eliminates all sliding bearings which previously gave considerable trouble through the accumulation of dust in the bearings or sliding surfaces which impaired the sensitivity of the recording mechanism.

The instrument can be operated at some three to four miles per hour or as fast as the operator can walk. When being moved from locations separated by only a few miles, it may be readily towed behind an automobile at a speed up to 20 miles per hour.

TEMPERATURE EFFECTS SHOWN

The accompanying photographs illustrate the several steps necessary to assemble the profilograph and the appearance of the unit in operation. The assembling operation will require about 10 minutes and it may be knocked down and loaded into a car in even less time.

To illustrate the type of record produced by the profilograph there are shown herewith facsimilies of records which were taken on actual pavements.

Graph "A" represents new pavement; record made in the early morning when the surface of the pavement was colder than the under side in contact with the subgrade.

"B." Same section recorded in the afternoon when the pavement surface temperature was higher than the subgrade temperature.

"C." Same section nine months later taken on a cloudy day in February where pavement temperature and moisture content were very uniform, showing the difference between summer and winter conditions.

INDICATES PAVEMENT CONTOUR

"F," "G," and "H" are included to illustrate the relationship between a profilograph record and an actual profile platted from level notes. The profilograph having an over-all length of some 13′ with a rigid span of only 10′ does not of course, indicate the major undulations in the pavement surface and for the same reason tends to diminish many of the larger irregularities.

A profilograph record should be regarded as evidence of the inequalities which tend to interfere with the smooth travel of the motor vehicle rather than as an exact replica of the pavement profile in space. On a whole, it appears that a profilograph record is an excellent indication of the pavement contour and does not tend to exaggerate the actual roughness other than that which is provided by the scale relationships used.

All of the examples shown were taken in the path followed by the left wheel of the car and the direction of traffic is from right to left.

It seems to be an old rule that before an engineer can be in a position to design improvements of any nature, it is first necessary to measure and evaluate the conditions. The profilograph offers means for providing a reasonably accurate recording of pavement surfaces and should be an aid in solving the difficult problem of designing and constructing pavements which are not only smooth when constructed but which will remain smooth after construction.

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