# United States Patent [19]

**Munyon et al.**

[11] **3,771,892**

[45] **Nov. 13, 1973**


[54] **MOBILE GRADE REFERENCE DEVICE FOR A PAVING MACHINE**


[75] Inventors: **Julian M. Munyon**, Big Rock; **Ronald W. Beaty**, Aurora, both of Ill.

[73] Assignee: **Barber-Greene Company**, Aurora, Ill.



[22] Filed: **Nov. 26, 1971**

[21] Appl. No.: **202,127**

[52] **U.S. Cl.** ..... **404/84,** 404/105

[51] **Int. Cl.** ..... **E01c 19/12**

[58] **Field of Search** ..... 94/46 R, 46 AC; 37/DIG. 20; 172/779, 780, 4, 4.5; 200/61, 44; 280/81 R, 104.5 R; 404/84, 105



[56] **References Cited**

UNITED STATES PATENTS

| | | | |
|---|---|---|---|
| 3,519,770 | 7/1970 | Long et al. | 94/46 AC |
| 3,259,034 | 7/1966 | Davin | 94/46 R |
| 3,272,099 | 9/1966 | Drake | 94/46 R |
| 2,720,716 | 10/1955 | White | 94/46 AC |

FOREIGN PATENTS OR APPLICATIONS

| | | | |
|---|---|---|---|
| 846,082 | 5/1939 | France | 94/46 R |
| K4752 | 5/1956 | Germany | 280/104.5 R |
| 1,056,865 | 10/1953 | France | 94/46 AC |

OTHER PUBLICATIONS

"Cedarapids Rubber Tired Asphalt Paver" Bulletin RP-2-5-68, Received Dec. 1968, pages 4 & 5



*Primary Examiner*—Roy D. Frazier
*Assistant Examiner*—Thomas J. Holko
*Attorney*—McDougall, Hersh & Scott



[57] **ABSTRACT**

Horizontally extending, articulated beams are connected to an asphalt paving machine adjacent one side thereof and extend longitudinally of the direction of travel of the paving machine. A grade reference stringline is mounted on the beams and is engaged by the sensor of screed control sensing means. A plurality of separate sub grade engaging skids are connected to the beams for supporting the latter; these skids are positioned longitudinally of the beams at randomly selected spacings. The skids are connected in pairs from sub beams, each of the latter being pivotally supported on its longitudinal midpoint.


**13 Claims, 9 Drawing Figures**

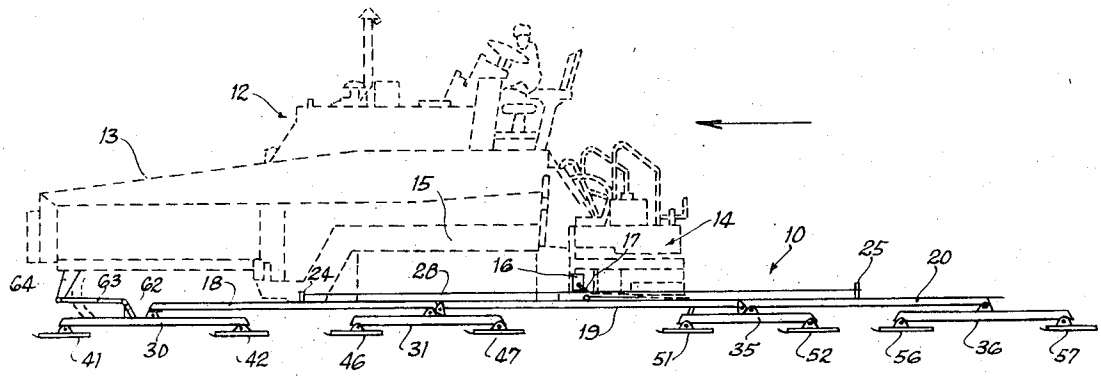


FIG. 1

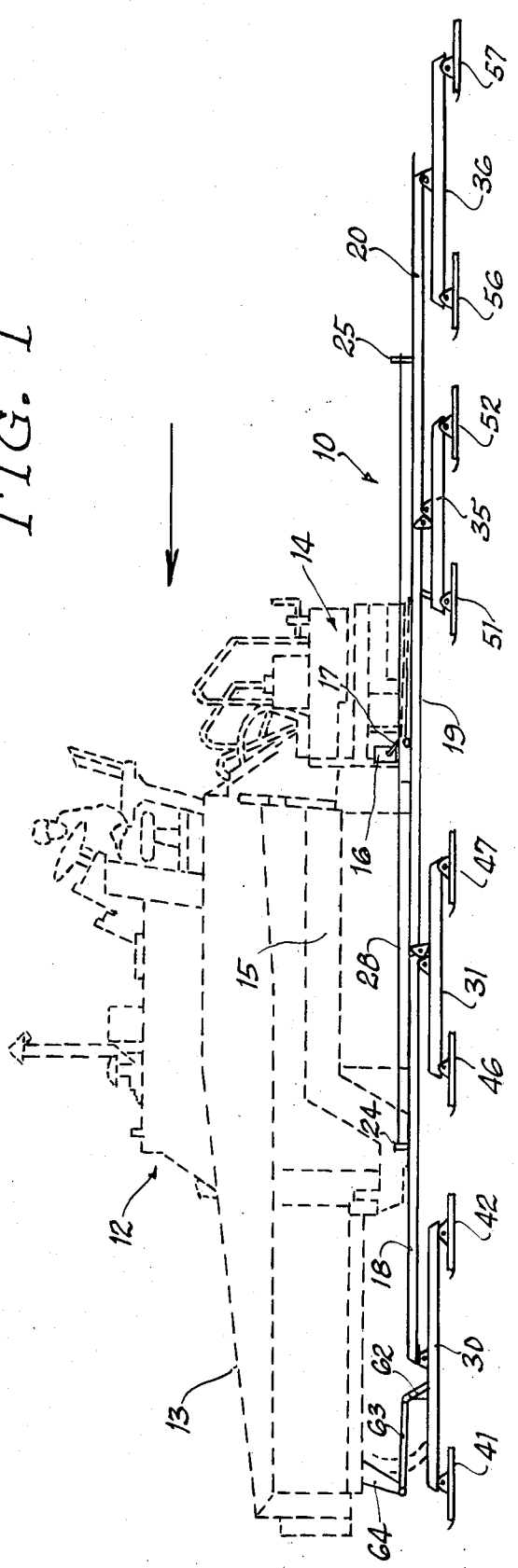

10
12
13
14
15
16
17
18
19
20
24
25
28
30
31
35
36
41
42
46
47
51
52
56
57
62
63
64

FIG. 2

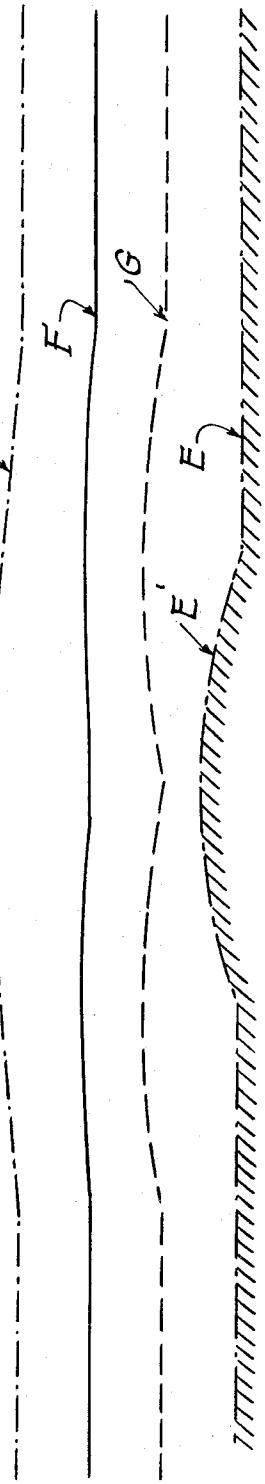

H
F
G
E'
E

FIG. 3a

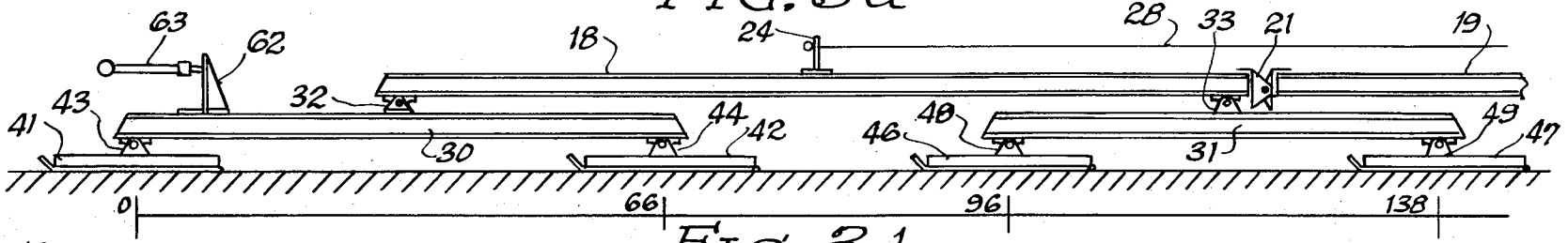



FIG. 3b

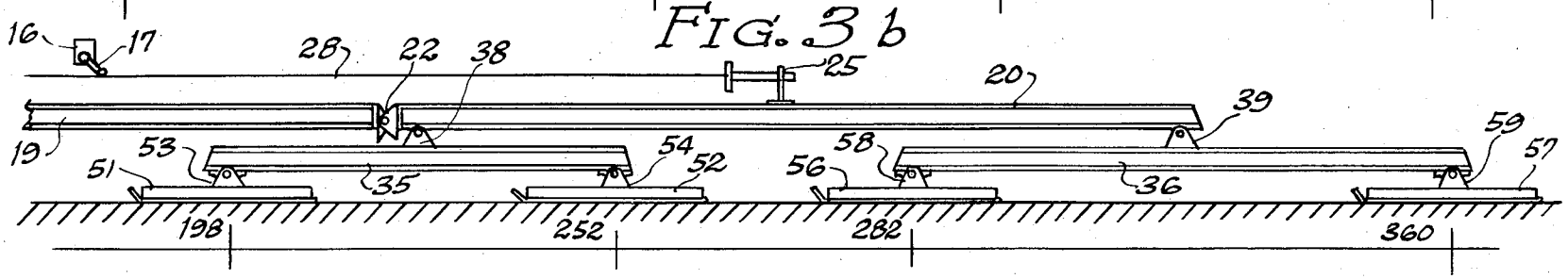



FIG. 4

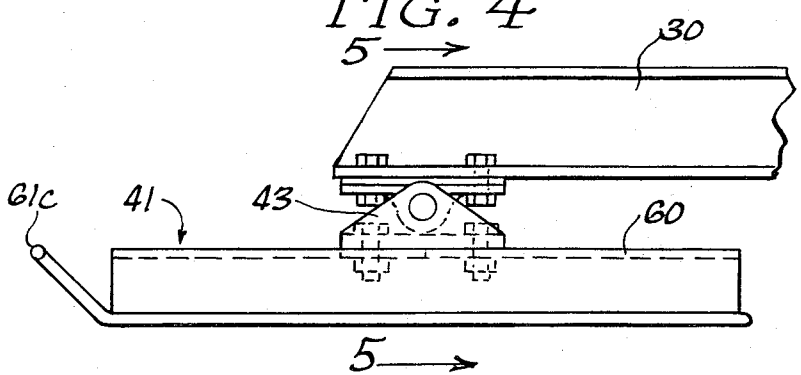
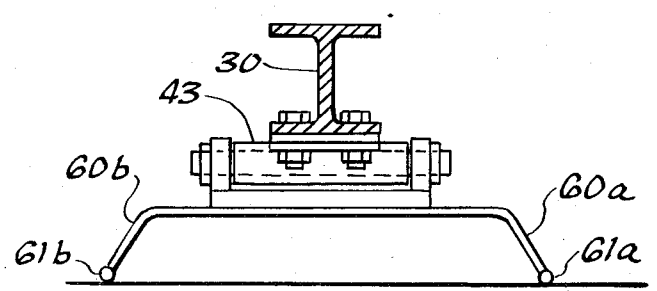



FIG. 5



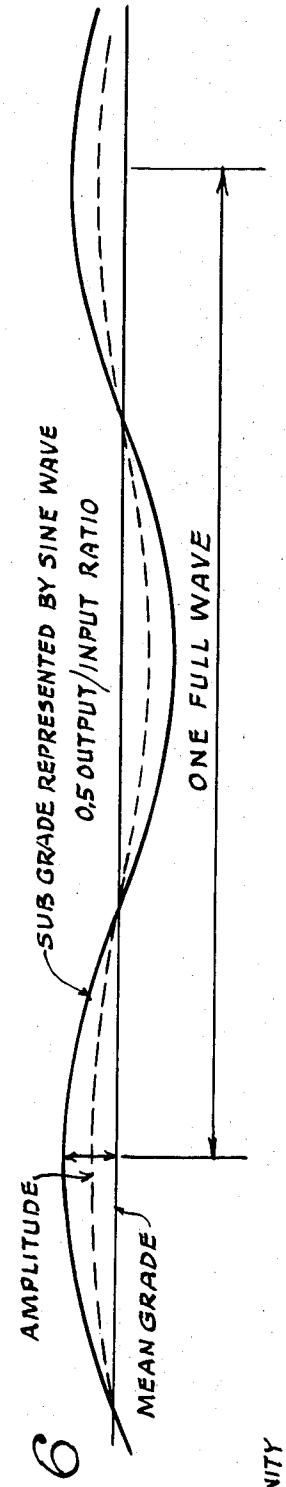

SUB GRADE REPRESENTED BY SINE WAVE
0.5 OUTPUT/INPUT RATIO
ONE FULL WAVE
AMPLITUDE
MEAN GRADE

FIG. 6

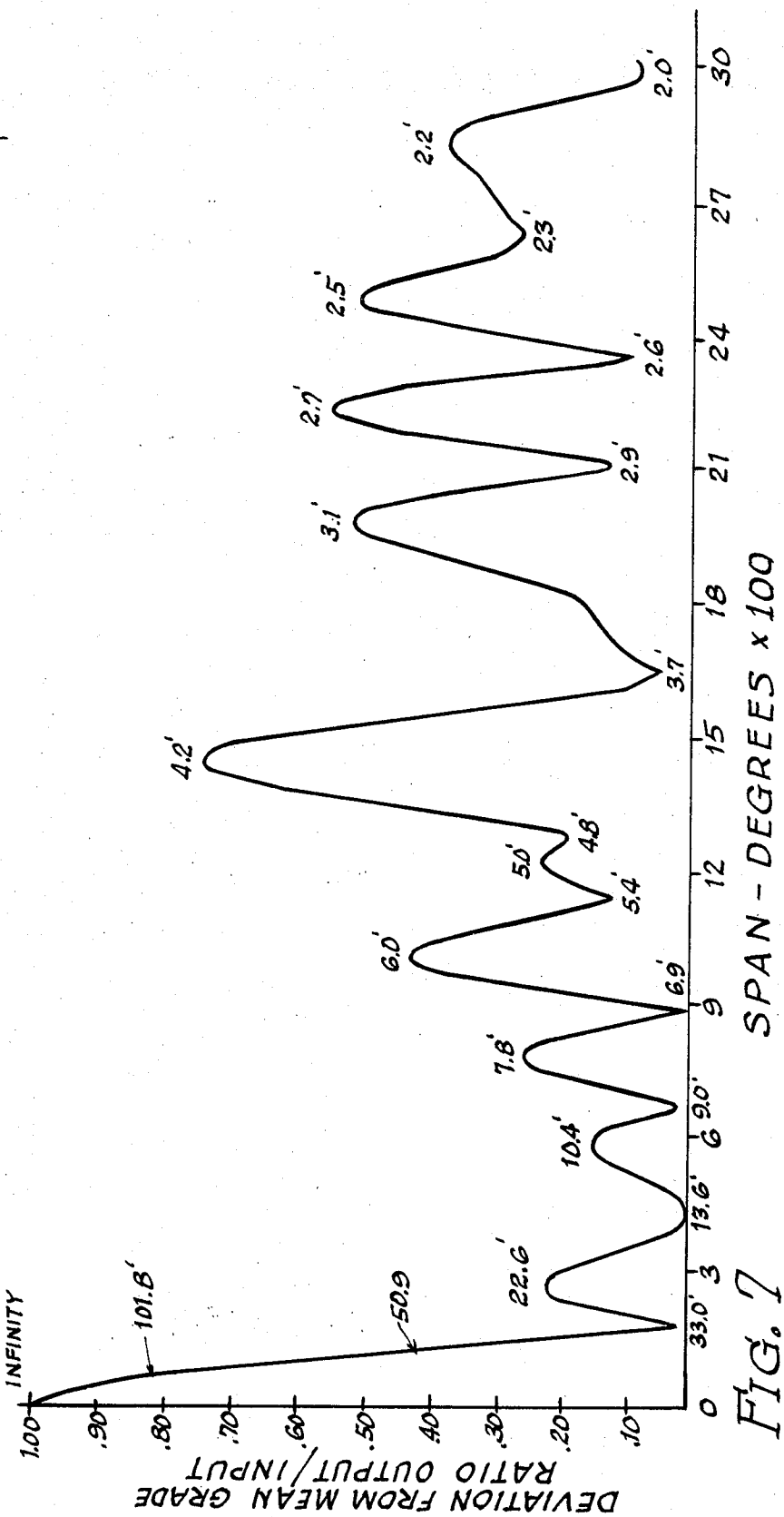

DEVIATION FROM MEAN GRADE
RATIO OUTPUT/INPUT
INFINITY
101.8'
50.9
22.6'
13.6'
10.4'
9.0'
7.8'
6.9'
6.0'
5.4'
5.0'
4.8'
4.2'
3.7'
3.1'
2.9'
2.7'
2.6'
2.5'
2.3'
2.2'
2.0'
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
0
3
6
9
12
15
18
21
24
27
30
33.0'
SPAN - DEGREES x 100

FIG. 7

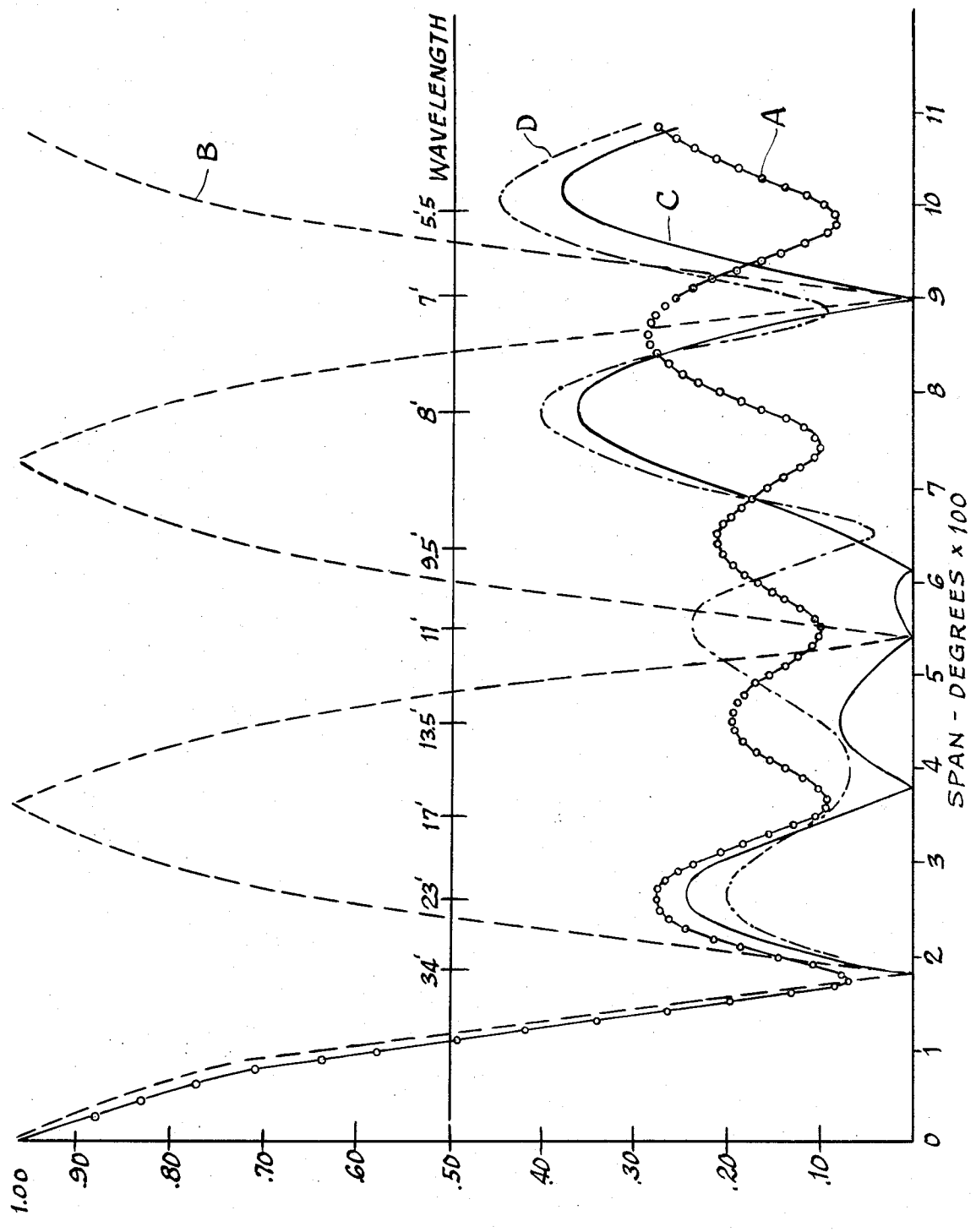

WAVELENGTH
5.5'
7'
8'
9.5'
11'
13.5'
17'
23'
34'
A
B
C
D
SPAN - DEGREES x 100
0
1
2
3
4
5
6
7
8
9
10
11
OUTPUT/INPUT RATIO
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10

FIG. 8

# MOBILE GRADE REFERENCE DEVICE FOR A PAVING MACHINE

## BACKGROUND OF THE INVENTION

1. Field of the Invention

The field of the present invention relates to paving machines, such as asphalt paving machines. Particularly, the present invention relates to a new and improved mobile grade reference device for such a paving machine.

2. The Prior Art

In the use of an asphalt paving machine, an external grade reference device, from which grade sensings are taken, is preferably provided. As is known to those skilled in the art, as asphalt paving machine adapted for use with an external grade reference device includes an automatic screed control system. Such system includes a feeler or sensor which engages the external reference wire or stringline. The external reference device establishes a reference plane independently of the paving machine; the reference plane is established prior to the time that the paver is active at any given point in its longitudinal path of travel. The feeler or sensor activates a control mechanism, usually hydraulically operated, to control the screed angle by raising or lowering the pivot points of the arms which mount the screed.

The external reference may be provided by means of a wire or stringline supported in parallel relation to the desired gradeline. An existing curb or adjacent pavement surface parallel to the desired grade may also be used as the external reference device. Under some conditions, it is desirable to use a mobile grade reference device including means constituting the reference line or plane. Such a device is towed along with the paving machine and rests on the sub grade or surface adjacent the sub grade. The term "sub grade" has reference to the surface which is to receive the material being laid by the paving machine, whether bituminous material or graded earth, or a layer of aggregate placed on the earth.

The mobile grade reference device just referred to may be categorized by two different types. The first type is constituted by a beam, ski or straight-edge, of some substantial length, e.g., at least equal to the span of the track or wheels of the paving machine, which spans hollows and sags and lengthens humps by providing a ramp action on either side of the hump thereby insuring a minimum thickness of material over such hump. The second type of mobile grade reference device under consideration may be characterized as an "averaging" device. This device may include a beam mounting two or more sub grade engaging wheels or skids or may be constituted by a flexible pipe or beam, in either case including a taut wire or stringline. If such device is mounted on wheels or skids, each wheel or skid may be individually sprung or connected to a system of levers, so that each wheel or skid maintains contact with the sub grade as the beam provides a support for the sensing member. This type of device averages the grade profile over which it is towed filling in hollows or sags and diminishing the height of humps by providing for thinner layers of material over the tops of such humps.

Heretofore, such mobile grade reference devices have been constructed in accordance with a definite geometric design. By definite geometric design, reference is had to uniform wheel or skid spacings. These



grade reference devices, although generally satisfactory, are not as accurate as desired in that they do not establish a pavement profile which fills in the hollows and diminishes the height of the humps to an optimum degree.

## SUMMARY AND OBJECTS OF THE INVENTION

The present invention may be summarized as relating to a mobile grade reference device which actuates the screed control sensing means with such a high degree of accuracy that the hollows and sags are filled with asphalt material and the humps covered with such material to provide the optimum pavement profile. Stated another way, the present invention relates to a mobile grade reference device providing optimum response characteristics consistent with certain practical considerations so that the end of the sensing arm of the screed control sensing means describes a path or profile in reasonably close conformity to the mean profile grade of an uneven sub grade thereby causing the paving machine to lay a pavement surface with a desirable profile. These results are achieved by random spacing of the sub grade engaging wheels or skids; in a preferred form of the invention, the wheels or skids are mounted such that all wheels or skids exert equal influences on the sensor.

A primary object of the present invention is the provision of a new and improved mobile grade reference device having the sub grade engaging support means positioned longitudinally of the device at randomly selected spacings.

Another object of the present invention is the provision of mobile grade reference device of the type described wherein the sub grade engaging supports are mounted such that they exert equal influences on the sensor of the screed control sensing means.

These and other objects and advantages of the present invention will become apparent from the following specification disclosing a preferred embodiment shown in the accompanying drawings.

## DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side elevational view of a mobile grade reference device constructed in accordance with the present invention, with the associated paving machine being shown in broken lines;

FIG. 2 is a graph representing a sub grade profile and three pavement profiles resulting from use, respectively, of an apparatus embodying the present invention and two prior art devices;

FIGS. 3*a* and 3*b* together constitute an enlarged side elevational view of the mobile grade reference device of FIG. 1;

FIG. 4 is an enlarged fragmentary side elevational view showing a typical connection between one of the sub grade engaging skids and the associated sub beam;

FIG. 5 is a section taken along the line 5—5 of FIG. 4;

FIG. 6 is a diagram graphically illustrating certain terms employed in analytically evaluating response characteristics of the preferred device of the present invention;

FIG. 7 is a graph showing response characteristics of the mobile grade reference device according to the present invention; and

FIG. 8 is a graph showing response characteristics of the preferred device of the present invention and re-

sponse characteristics of other mobile grade reference devices.

## DESCRIPTION OF A PREFERRED EMBODIMENT

Referring particularly to FIG. 1, a mobile grade reference device constructed in accordance with the present invention is generally designated **10**. The asphalt paving device, which of itself forms no part of the present invention, is well known to those skilled in the art and is defined by a self-propelled vehicle, generally designated **12**, suitably supported by wheels or crawlers on endless tracks. The paving machine includes a hopper **13** for receiving the paving material. The machine also includes a screed assembly generally designated **14**, which screed assembly is pivotally mounted from the trailing ends of a pair of draft arms, one arm being shown and designated **15**. The paver is provided with a suitable control system for raising and lowering the pivot points at the forward ends of the draft arms. If the forward ends of the draft arms are raised, the screed **14** will gradually climb a slope constituted by the paving material until the screed levels off under its own action thereby forming a thicker layer of material. Lowering of the front end of the draft arms will produce the opposite effect and will result in the production of a thinner layer of paving material.

The paver includes an automatic screed control system which may be of the type shown in Munyon U.S. Pat. No. 3,285,148, assigned to the assignee of the present invention. Such a screed control system includes a sensor control **16** having a feeler arm **17**. This arm feels or contacts a reference line which is at a predetermined position and which is established independently of the paver by the grade reference device which forms the subject matter of the present invention. The position of the reference line is established prior to the time the paver is active at a given point in its path of travel, which is from right to left as seen in FIG. **1**. The sensor or feeler arm **17** actuates the screed control mechanism which causes the screed or draft arms **15** to follow the external reference line or plane independently of any motion of the paving machine thereby maintaining a substantially uniform angular relationship between the screed and the reference line.

Referring now to FIGS. **1**, **3***a* and **3***b*, the mobile grade reference device **10** includes three articulated beams **18**, **19** and **20**, the beam **19** being pivotally connected to the other two beams by suitable pivot connections **21**, **22**. Beams **18** and **20** support respective uprights **24**, **25** at their longitudinal midpoints, which uprights mount a wire or stringline **28**. This stringline is engaged by the sensor arm **17** and establishes the external reference line referred to above.

The grade reference device **10** includes a pair of sub beams **30**, **31**, the latter being respectively connected at their longitudinal midpoints to the beam **18** adjacent the ends of the latter by pivot joints **32**, **33**. Similarly, the grade reference device includes another pair of sub beams **35**, **36**; these members are connected at their respective longitudinal midpoints by pivot connections **38**, **39** to the beam **20** adjacent the ends of the latter.

A pair of sub grade engaging elements in the form of skids **41**, **42** are pivotally mounted to the ends of the sub beam **30** by pivot connections **43**, **44**, respectively. The sub beam **31** is connected to a pair of skids **46**, **47** by respective pivot connections **48**, **49**. Similarly, the sub beam **35** is supported from a pair of skids **51**, **52** through respective pivotal connections **53**, **54**. Finally, the sub beam **36** is connected to skids **56**, **57** by pivotal connections **58**, **59**, respectively.

The skid **41** is shown in FIG. **4** and will be seen to include a plate member **60** having bent downwardly and outwardly extending side portions **60***a*, **60***b* respectively connected to longitudinally extending portions **61***a*, **61***b* of a rod having a transversely extending portion **61***c*. It will be understood that the construction of the other skids is identical to the construction of the skid **41**.

The sub beam **30** mounts an upright bracket **62** which is connected to a rod **63**, the latter having its forward end pivotally connected to a bracket **64** (FIG. **1**) on the paving machine **12**. Accordingly, the mobile grade reference device **10** is towed by the paving machine and extends adjacent one side thereof longitudinally of the direction of travel of the machine.

According to one of the important principles of this invention, the skids are not spaced equidistant of each other longitudinally of the grade reference device or according to a definite geometric design but rather are positioned at random spacings. These random spacings may be derived from the use of conventional random data tables or any other suitable technique to achieve random data.

In deriving the random figures, certain parameters dictated by practical considerations must be taken into consideration. These parameters include maximum over-all length of the mobile grade reference device, the number of sub grade engaging elements, and the minimum spacing between these elements or skids which in turn is affected by the length of each skid. In the preferred embodiment of the mobile grade reference device of this invention, eight skids are employed with the center-to-center distance between leading and trailing skids in the order of 30 feet.

Taking the aforesaid factors into consideration, the following values were derived from a random table for spacing the eight skids of the mobile grade reference device according to the preferred form of the present invention: **66**; **96**; **138**; **198**; **252**; **282**; **360**. These randomly selected numbers, which are set forth graphically in FIGS. 3a and 3b, produce the following spacing of the skids (measured between their respective axes of pivot) proceeding from left to right as seen in FIGS. **3***a* and **3***b*: 5.11 feet; 3.40 feet; 4.22 feet; 5.68 feet; 3.82 feet; 2.90 feet; 5.22 feet. Of course, the invention is not to be limited to these particular spacings as other randomly selected numbers will provide different spacings. It will be understood that any randomly selected set of numbers utilized in the construction of a device according to the present invention would have to provide for adequate clearance between adjacent wheels or skids.

The sub beams are necessarily of different lengths to accommodate this random spacing of the skids. However, each sub beam is pivotally mounted to the beam **18** or **20** at the longitudinal midpoint of the former.

The response characteristics of the mobile grade reference device according to this invention have been analytically determined. A sine wave was selected as most closely approximating the type of unevenness or irregularity commonly found in the average sub grade profile. The sine wave represents the sub grade profile better than any other pure mathematical form. The use of a sine wave for analysing frequency response of the grade

reference device of the present invention is valid. The frequency response approach using a sine wave is commonly used in the design and analysis of other systems, such as automatic control systems, for example.

Referring now to FIG. 6, a sub grade is represented by a sine wave. The amplitude of the sine wave represents the maximum deviation from the means grade. The term "wave" means the distance between any two common points on the sine wave — in FIG. 6 a full wave is represented between the maximum amplitude of a sub grade profile hump to the maximum amplitude of the adjacent hump.

In the two graphs of FIGS. 7 and 8, the ordinant values are expressed as output/input ratios. The optimum output/input ratio is zero; this indicates a pavement profile precisely parallel with the means grade of the sub grade. An output/input ratio 1.00 indicates no averaging whatsoever resulting in the pavement profile precisely following the sub grade profile. By way of example, FIG. 6 illustrates by a broken line an output/input ratio of 0.5. Such ratio indicates that the pavement profile has lowered the humps and filled in the hollows to a 50 per cent extent.

Assume that the point established by engagement of sensor arm 17 and stringline 28 constitutes a sensing point for the mobile grade reference device. The profile established by this sensing point during longitudinal movement of the mobile grade reference device is the "output" of the latter. The profile of the sub grade engaged by the mobile grade reference device is the "input" of the system. If the output is the same as the input, this means that the profile established by the sensing point is the same as the sub grade profile. In this case no leveling is achieved as the mobile grade reference device is 100 percent inefficient — the output over input ratio is one over one or 1.00.

On the other hand, assume that the mobile grade reference device is 50 percent efficient, i.e.., it causes the sensing point to describe a profile having humps lowered, with respect to the mean grade profile, by 50 percent from the humps on the sub grade and having hollows raised, with respect to the mean grade profile, by 50 percent from the hollows on the sub grade. In this example, the output can be considered as one half the input thereby establishing an output over input ratio of 0.5.

FIG. 7 shows the response characteristics of the grade reference device as determined by computer analysis. This graph shows output/input ratios from a minimum wavelength of 2.0 to a wavelength of infinity. The term "wavelength" may be expressed by the following formula:

wavelength = [ 360 × Characteristic Dimension (C.D.)/angle spanned by C.D. ]

The characteristic dimension (C.D.) is constituted by the distance between the pivot axis of the leading skid to the pivot axis of the trailing skid of the mobile grade reference device. The angle spanned by C.D. is an expression of the ratio between C.D. and the dimension of a wave. For example, a grade reference device with a C.D. of 30 feet on a wave of 30 feet equals a span of 360°; a device with a C.D. of 30 feet on a 15 foot wave equals a span of 720°. In FIG. 7, the abscissa values are expressed as span in degrees.

FIG. 8 shows four computer derived response characteristic curves. The response characteristics of the preferred embodiment of the present invention are shown by curve A. The response characteristics of a 30 foot, two wheel grade reference device are shown by curve B; it will be noted that this curve is of a repetitive cyclic nature which is undesirable. Curve C represents a thirty foot, eight wheel grade reference device with equal spacing between the wheels, but with the wheels being mounted in pairs from respective sub beams, each being pivotally mounted at its longitudinal midpoint. Curve D represents the response characteristics of a grade reference device the same as the device represented by graph C, except that the former does not have the sub beams pivotally mounted at their respective midpoints.

By reference to FIG. 8, it is seen that the present invention represented by curve A produces the lowest average output/input ratio. It is observed that curve A does not include repetitive portions. The device represented by graph C, with equal spacing between the sub grade engaging wheels and with each of the sub beams being mounted at its midpoint, provides the next lowest average output/input ratio.

With reference to mounting the sub grade engaging members in pairs from sub beams each pivotally mounted at its midpoint, it will be understood that mathematically such sub beams act as a computer in that they add the vertical motion of each wheel or skid and divide by the number of such wheels or skids. In other words, in such an arrangement the influence of each wheel or skid on the pivot center of the sub beam is at a minimum when the lever ratios of the two skids or wheels are equal and all wheels or skids exert equal influences on the sensor. It will be appreciated that when an even number of sub grade engaging support members are used, one of the most practical ways of achieving equal influence by such support members is to mount the same in pairs from beams each pivotally mounted at its midpoint. Of course, the invention is not to be limited to the use of an even number of sub grade engaging support members, such as skids or wheels. When an odd number of sub grade engaging support members are employed, the geometry, involving the various beam lengths and their pivot points which determine beam ratios, is such that the support members exert equal influences on the sensor.

At this time it should also be mentioned that although the embodiment of the present invention is shown with sub grade engaging skids, the present invention is not to be limited to such elements. Wheels or other suitable sub grade engaging members may be used.

It will be understood that accuracy of the grade reference device of the present invention is proportional to the number of sub grade engaging members — the lowest deviation or lowest output/input ratio is achieved with the greatest number of such elements. The embodiment of the present invention includes eight skids which is believed to be a preferred number because of practical considerations; however, the invention is not to be limited to a grade reference device with that particular number of sub grade engaging elements.

It should be apparent that the present invention provides a new and improved mobile grade reference device having response characteristics such that the screed control sensing system of the paver will be actuated to lay a pavement having a highly desirable profile. The present invention achieves this objective by the randomized positioning of the sub grade engaging elements and also by mounting the sub grade engaging ele-

ments in a manner such that they exert equal influences on the sensor.

FIG. 2 schematically illustrates a sub grade E having a hump E' extending for thirty feet longitudinally of the direction of movement of the paving machine. The grade reference device of the present invention results in a pavement profile represented by the line F; it will be noted that the hump E' has been substantially leveled. The device represented by curve B in FIG. 8 would produce a pavement profile indicated by the line G in FIG. 2. A thirty foot rigid beam with no skids or wheels would result in a pavement designated by the line H in FIG. 2.

We claim:

1. A mobile grade reference device for a paving machine comprising:
   a. horizontally extending, articulated beam means arranged longitudinally of the direction of travel of said paving machine;
   b. grade reference means responsive to the position of said beam means and engaged by screed control sensing means on said paving machine; and
   c. at least four separate sub grade engaging support means connected to said beam means for supporting the latter, at least a majority of said support means being positioned longitudinally of said beam means at randomly selected unequal spacings.

2. The device according to claim 1 further defined by:
   a. said support means being connected in pairs from opposite ends of respective sub beams constituting a portion of said beam means; and
   b. pivot means pivotally mounting each sub beam at its longitudinal midpoint to respective other beams forming another portion of said beam means.

3. The device according to claim 2 wherein said beam means includes at least four sub beams.

4. The device according to claim 2 further defined by:
   a. said beam means including four of said sub beams;
   b. said other beams including a first beam having its opposite ends respectively engaged with two of said pivot means thereby being connected with the corresponding pair of sub beams;
   c. said other beams also including a second beam having its opposite ends respectively engaged with the other two of said pivot means thereby being connected with the corresponding pair of said sub beams; and
   d. said grade reference means being supported by said first and second beams.

5. The device according to claim 4 wherein each of said support means is constituted by a skid member pivotally connected to the associated sub beam.

6. The device according to claim 4 wherein said beam means is approximately 30 feet in length.

7. The device according to claim 1 wherein said beam means includes a plurality of beams pivotally engaged with said support means such that the latter exert equal influences on said sensing means.

8. The device according to claim 7 wherein each of said support means is constituted by a pivotally mounted skid.

9. A mobile grade reference device for a paving machine comprising:
   a. horizontally extending, articulated beam means arranged longitudinally of the direction of travel of said paving machine;
   b. grade reference means responsive to the position of said beam means and engaged by screed control sensing means on said paving machine;
   c. said beam means including a plurality of pivotally connected beams; and
   d. at least four separate sub grade engaging support means connected to said beams such that all of said support means exert equal influences on said sensing means, at least a majority of said support means being longitudinally positioned at randomly selected unequal spacings.

10. The device according to claim 9 wherein said beam means includes four of said beams, each beam being connected to a pair of support means.

11. The device according to claim 9 wherein said beam means includes four of said beams, each beam being connected to a pair of support means.

12. The device according to claim 9 further defined by:
   a. said beam means including four of said beams;
   b. said beam means also including a first beam having its opposite ends respectively pivotally connected to the longitudinal midpoints of a pair of said beams; and
   c. said beam means further including a second beam having its opposite ends respectively pivotally connected to the longitudinal midpoints of the other pair of said beams.

13. The device according to claim 12 wherein said beam means is approximately thirty feet in length.

* * * * *