APPENDIX B

APPLICABILITY OF THE RAINHART PROFILOGRAPH AS A SPECIFICATION TOOL FOR LOUISIANA PAVEMENTS
(PARTIAL REPRODUCTION -- MASTERS THESIS)

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APPLICABILITY OF THE RAINHART PROFILOGRAPH AS A SPECIFICATION TOOL FOR LOUISIANA PAVEMENTS

(PARTIAL REPRODUCTION)

A Thesis

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By
David Oren Cox
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APPLICABILITY OF THE RAINHART PROFILOGRAPH AS A SPECIFICATION TOOL FOR LOUISIANA PAVEMENTS

(PARTIAL REPRODUCTION)

Induced Roughness Tests

Having demonstrated the graphical repeatability of the Rainhart both over a substantial period of time and through a variety of variables, the results of this first group of tests were then used as a base value upon which to judge the results of a second series of tests.

This second series of tests has been identified as the "Induced Roughness" tests. These tests were designed to evaluate the ability of the Rainhart to accurately determine known values of roughness in a wide variety of situations. The tests were structured in such a manner as to subject the machine to numerous roughness patterns and different size deviations in an attempt to determine the accuracy of both the digital and the graphical outputs. These roughness patterns were chosen to approximate either those which may occur during construction or which might be present in a pavement being evaluated for rehabilitation.

The tests were conducted at the same Thompson Creek site described earlier, but this time bumps and depressions in the pavement profile were artificially created using pieces of plywood and masonite. These sheets of plywood were 8 feet long and 4 feet wide with thicknesses ranging in 1/8-inch increments from 1/8 inch to 1 inch. They were placed on the pavement surface with the long axis perpendicular to the test centerline so that each deviation was shown on the profile as being 4 feet long. This 4-foot deviation size was purposely chosen as being representative of actual field conditions as previous research has shown that the common size of a surface profile deviation is between 4 and 6 feet long for many types of paving methods and equipment.[5]

It was originally thought that these artificial deviations would have to be physically secured to the pavement to prevent movement during testing. However, preliminary tests showed that this was not necessary and instead, where

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[5]Shah, S. C., A Correlation of Various Smoothness Measuring Systems for Asphaltic Concrete Surfaces, Louisiana Highway Research and Development Section, 1974.

additional support was necessary, the individual boards were held in place by weighting them with sandbags.

This series of tests encompasses ten different test patterns which were established to represent roughness situations with varying deviation sizes, a range of deviation spacings, differing deviation amplitudes and lengths, and includes both positive (bumps) and negative (holes) deviations (see Appendix C). Each test pattern was run twice as a further test of repeatability under these extreme test conditions.

These induced roughness tests are discussed below either individually or, where appropriate, in similar groups. All of these tests were conducted in June of 1984. In an attempt to minimize the effects of the change in the digital readings over time, the digital readings obtained during these tests are compared only to those control readings obtained in May 1984. However, the graphical results are compared to the average of the entire series of graphical control tests.

Induced Roughness Test No. 1

The purpose of this test was to determine the response of the profilograph to deviations of a known height encountered on an individual basis. The test was also intended to measure the accuracy of the graphical display both vertically and longitudinally as well as to give an indication of the accuracy of the 0.1-inch digital filter.

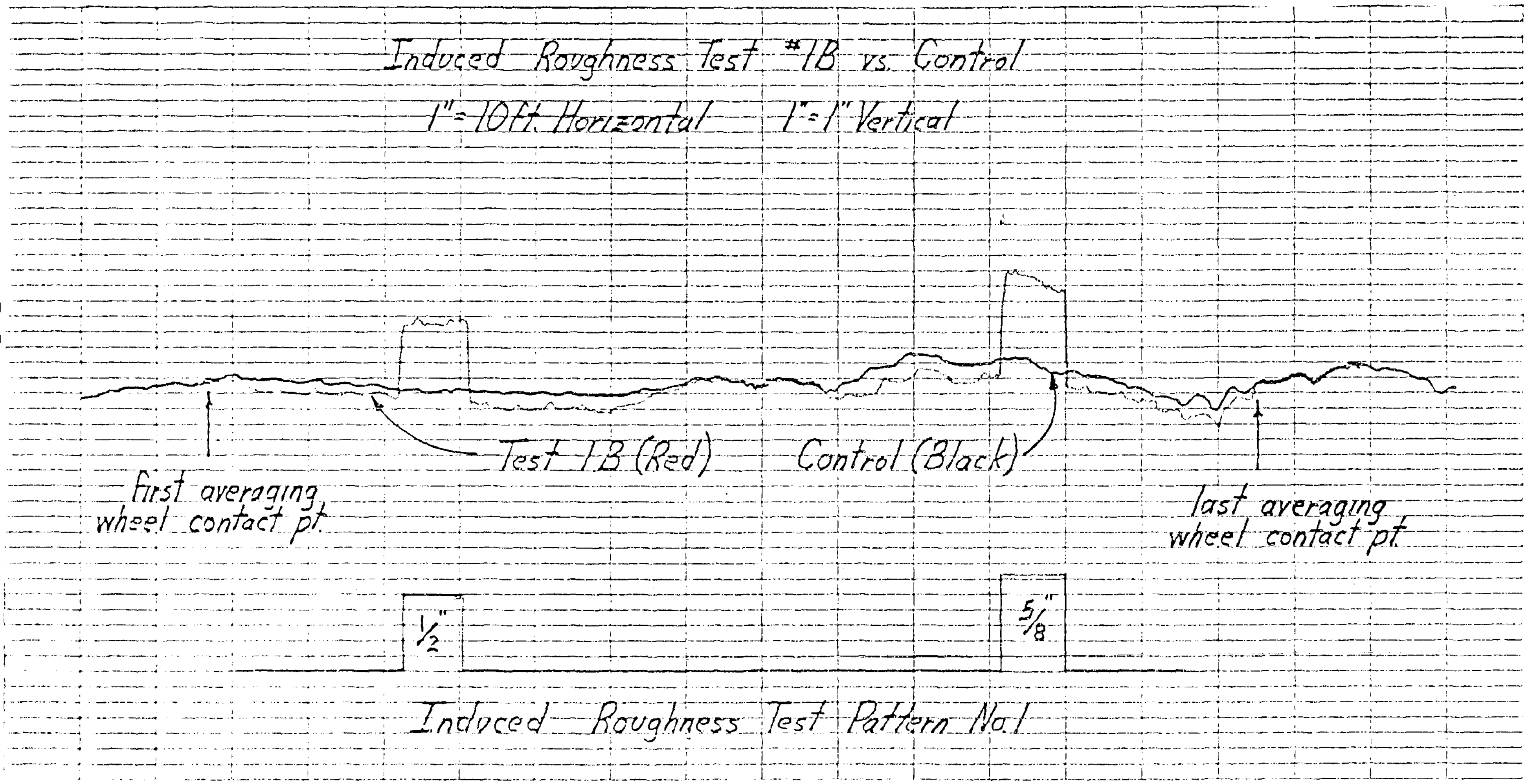
In all a total of 1.75 inches of induced roughness was added to the test section at five different locations. The individual deviations varied in height from 1/8 inch to 5/8 inch and were spaced widely enough so that all the wheels of the profilograph could traverse one deviation prior to encountering the next.

Results - Test No. 1

The graphical display successfully plotted the beginning and ending location of each deviation with an accuracy of ± 0.5 foot. The width of these four-foot deviations was shown graphically as being 4 feet at the top of the vertical display but as varying between 4 and 5 feet wide at the bottom of this display.

Vertically, the height of the deviations was accurately displayed within 1/16 inch of the actual height of the deviation even for the 5/8-inch board. It was noted on the graph that the profile in the vicinity of the 5/8-inch board was shown to be as much as 1/10 inch lower than its actual location as depicted on the control profiles (see Figure 9). This is a good illustration of the effects of the averaging wheels. When the averaging wheels in advance of the measuring wheel encounter a high spot in the pavement, they lift the platform or frame of the profilograph which in turn causes the measuring wheel to give a false indication of a

Figure No. 9



Induced Roughness Test #1B vs. Control
1" = 10 Ft. Horizontal 1" = 1" Vertical
Test 1B (Red)
Control (Black)
first averaging wheel contact pt.
last averaging wheel contact pt.
1/2"
5/8"
Induced Roughness Test Pattern No. 1

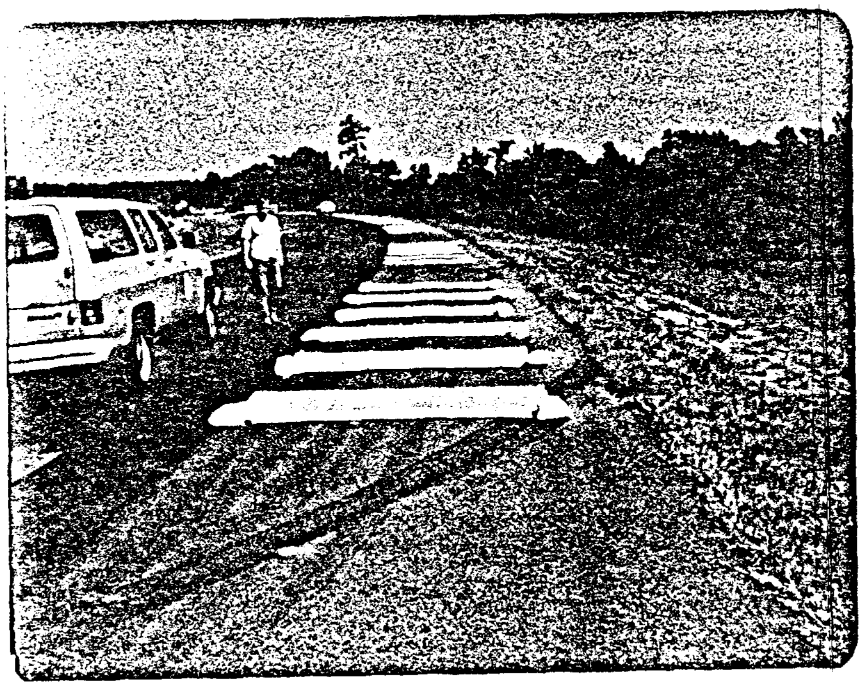
depression on the graph. In this test a maximum of two averaging wheels was always on the four-foot-wide board. Thus for the 5/8-inch board this false depression should have been shown as 5/8" x 2(1/12) or approximately 0.1", almost precisely its actual measurement.

The digital recorder showed the section to contain 7.02 total inches of roughness and 4.05 inches using the 1/10-inch filter, an increase of approximately 3.25 total inches and 2.1 filtered inches as compared to the actual addition of 1.75 inches of roughness. Thus, both of the digital displays overstated the actual increase in roughness. The graphical methods also overstated the increase in roughness, showing the addition of approximately 2.1 inches.

Induced Roughness Tests No. 2 and No. 3

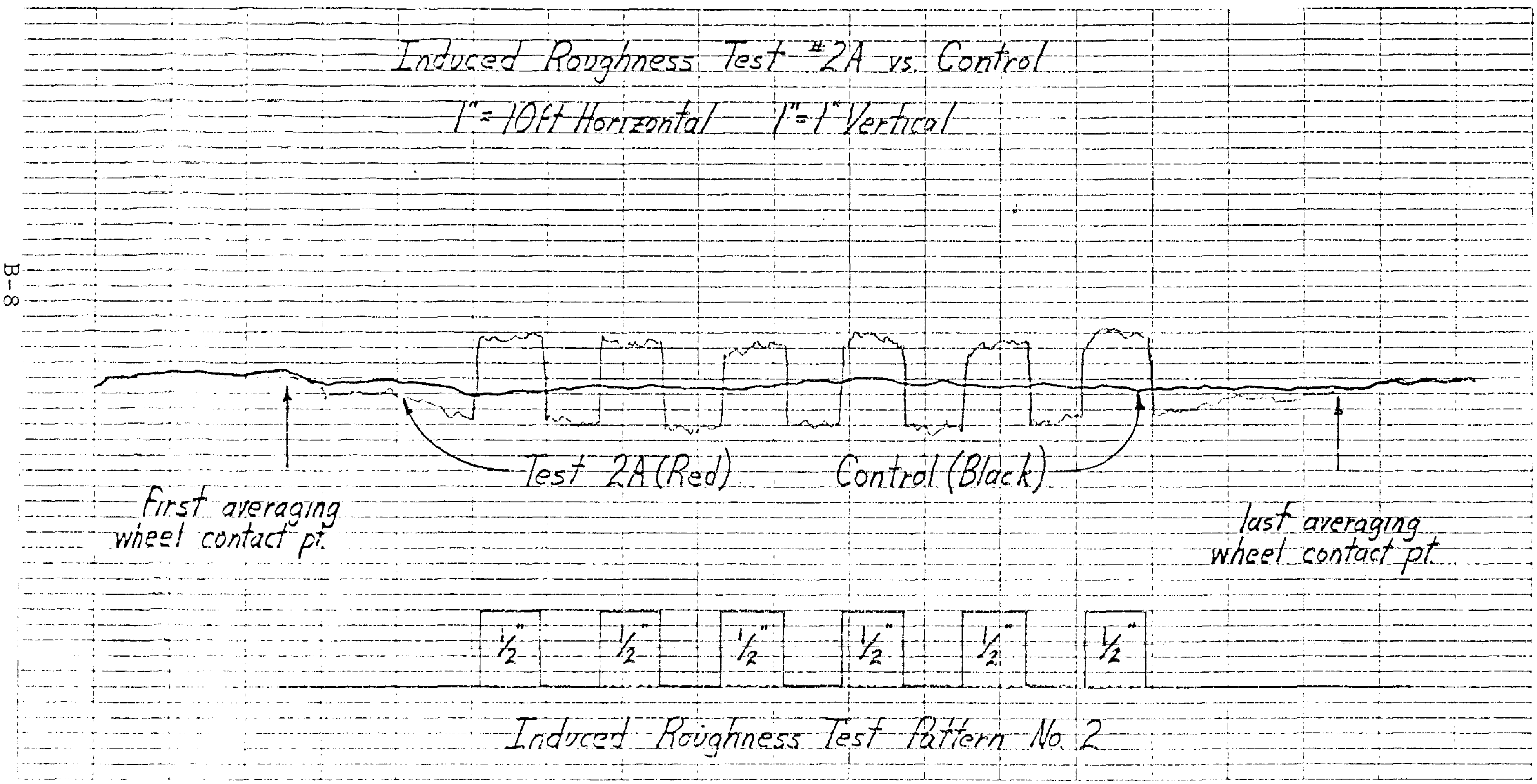
The purpose of these tests was to determine the response of the profilograph to a series of grouped deviations. As in the previous test, these deviations range from 1/8 inch to 5/8 inch in height in 1/8-inch increments. However, in these tests six deviations of each height, each four feet wide, were spaced in a group with four feet between deviations. This resulted in several test patterns each 44 feet in length, a distance sufficiently long so as to engage all of the averaging wheels at the same time. The individual groups of deviations were however, sufficiently separated so as to allow the profilograph to completely disengage from one set

FIGURE 10



INDUCED ROUGHNESS TEST PATTERN NO. 2

Figure No. 11



Induced Roughness Test #2A vs. Control
1" = 10 ft Horizontal 1" = 1" Vertical
Test 2A (Red)
Control (Black)
First averaging wheel contact pt.
last averaging wheel contact pt.
1/2"
1/2"
1/2"
1/2"
1/2"
1/2"
Induced Roughness Test Pattern No. 2

prior to encountering the next set (see Figure 10).

In both tests No. 2 and No. 3 a total of 7.5 inches of induced roughness was added to the control section. However, test pattern No. 2 contained a set of six 1/8-inch boards while the smallest boards used in the third test pattern were 1/4 inch high. Thus presumably the unfiltered roughness of both runs should have been the same while it would be expected that the filtered readings would be lower for test No. 2 than test No. 3.

Results - Tests No. 2 and No. 3

Again it is clear that the profilograph very accurately located the longitudinal position of the test bumps, in all cases plotting them graphically within 0.5 foot of their measured location. The overall height of the bumps, that is the size of the vertical deviations, was also shown quite accurately especially for the 1/8-inch and 1/4-inch groups. In the larger groups, the vertical height of the deviation as measured from the graphical output, ranged from 0.05 inch to 0.15 inch larger than the actual height of the deviations.

The effects of the averaging wheels was again revealed when comparing the induced roughness graphs to the control graphs at the same location. From the point at which the first averaging wheels of the profilograph engage the first raised board the roadway profile is shown as steadily descending from its "true" position. This continues to the point where the measuring wheel encounters that first bump, at which point this "depression" is approximately one-fourth the height of the board. This "depressed" reading for the original ground continues as the profilograph continues across the raised boards. Near the center of the set, where the averaging wheels are equally divided between those supported by the raised deviations and those supported by the original ground, the "depressions" are shown to actually descend as far below the true grade as the projections are shown to raise above it (see Figure 11). As might be expected, when the averaging wheels begin to exit from the raised boards, the elevation of the "original ground" indication also begins to raise again until it returns to its true position when the last averaging wheel leaves the last board.

As predicted, the filtered readout of the test No. 2 run was lower than that of test No. 3. In fact, the average filtered readout of run No. 2 was approximately 0.7 inch lower than that of the third run. It is presumed that this is primarily due to the fact that the six 1/8-inch boards are just barely discernible above the 1/10-inch filter in the second run, while the third run contained none of the smaller 1/8-inch deviations. However, the unfiltered readings of the third run are also lower than the unfiltered readings of the second run. This discrepancy between the unfiltered readings can probably be attributed to the previously discussed tendency of the profilograph to exaggerate the height of the deviations in excess of 1/4 inch high which were more numerous in the third test pattern than in the second.

A comparison was made between the graphical display of the grouped boards to the graphical display of single boards of the same height. This revealed that the 1/8-inch deviations were shown in a virtually identical manner whether encountered singly or in a group. The 1/4-inch deviations were consistently shown to be slightly larger than 1/4 inch (approximately 0.3 inch) when in a group except for the last deviation of those six encountered by the profilograph. This was almost identical to the display of the single 1/4-inch deviation and was shown accurately to be 0.25 inch high. The grouped 3/8-inch boards were almost identical in size and height to the single 3/8-inch board, but both displays measure approximately 0.425 inch high as opposed to the actual 0.375-inch height. However, it should be noted that the original ground at the site of the 3/8-inch group was quite rough, making comparisons difficult. The 1/2-inch display compared in a manner very similar to the 1/4-inch display with the individuals in the grouped set being shown on an average as approximately 0.1 inch higher than they actually are.

As stated earlier, in each test a total of 7.5 inches of induced roughness was added to the control section. Yet, the unfiltered digital readout exceeded the average control value by approximately 11.6 inches for test No. 2 and a surprisingly high 13 inches for test No. 3. The 0.1-inch filtered digital readout exceeded the control average by approximately 9 inches in test No. 2 and 9.7 inches in test No. 3. Finally, the graphical display was rated by the 0.1-inch blanking band to have increased 7.25 inches for test No. 2 and 7.65 inches for test No. 3.

As with test No. 1, both digital readouts for tests No. 2 and No. 3 greatly exaggerated the actual roughness contained in the test sections, the worst of these being the unfiltered readouts which indicated an average of 64% more roughness than was actually present. The filtered readings did better but were themselves approximately 25% above the actual roughness. Only the graphical calculations accurately indicated the total amount of induced roughness, showing that an average of 7.45 inches or 99% of the actual value was added to the test course.

The fact that the graphical blanking band calculations are so close to reality in these tests was unexpected. After all, the blanking band actually subtracts 0.1 inch from the roughness of each deviation. However, this subtracted 0.1 inch appears to have been almost exactly replaced by the exaggerated height which is shown graphically for the deviations over 1/4 inch high. This unexpected coincidence increases the credibility of this method of calculating roughness and offers an added reason for using the 0.1-inch blanking band instead of the 0.2-inch blanking band.

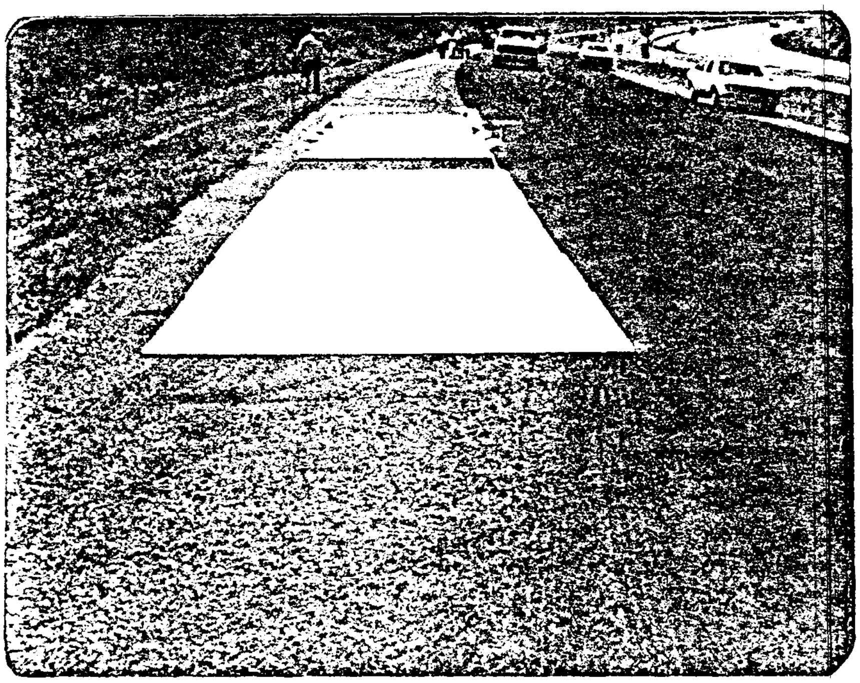
Induced Roughness Tests No. 4, No. 5 and No. 6

The purpose of these tests was to determine the response of the profilograph to a simulated depression in the pavement surface. This depression was constructed of boards laid edge to edge for a total distance of 24 feet. This elevated pattern was followed by a four-foot section of original ground, which in turn was followed by another 24-foot section of boards laid end to end. Test run No. 4 was constructed using 3/8-inch-thick boards, test No. 5 used 1/2-inch boards, and test No. 6 used 5/8-inch boards. Thus, a "hole" four feet wide and either 3/8, 1/2 or 5/8 inch deep was simulated between these two raised surfaces (see Figure 12). In all a total of 0.75 inch of induced roughness was added to the test section in run No. 4, 1.0 inch in run No. 5 and 1.25 inches in run No. 6.

Results - Test No. 4

Again, the graphical plot was extremely accurate in locating the longitudinal position or "station" of the test boards. The most interesting feature in this regard was the width of the 4-foot gap which was shown to be exactly 4 feet at the top of the "hole" but quickly tapered to near 3-1/2 feet at the bottom of the "hole." This is in stark contrast to the

FIGURE 12

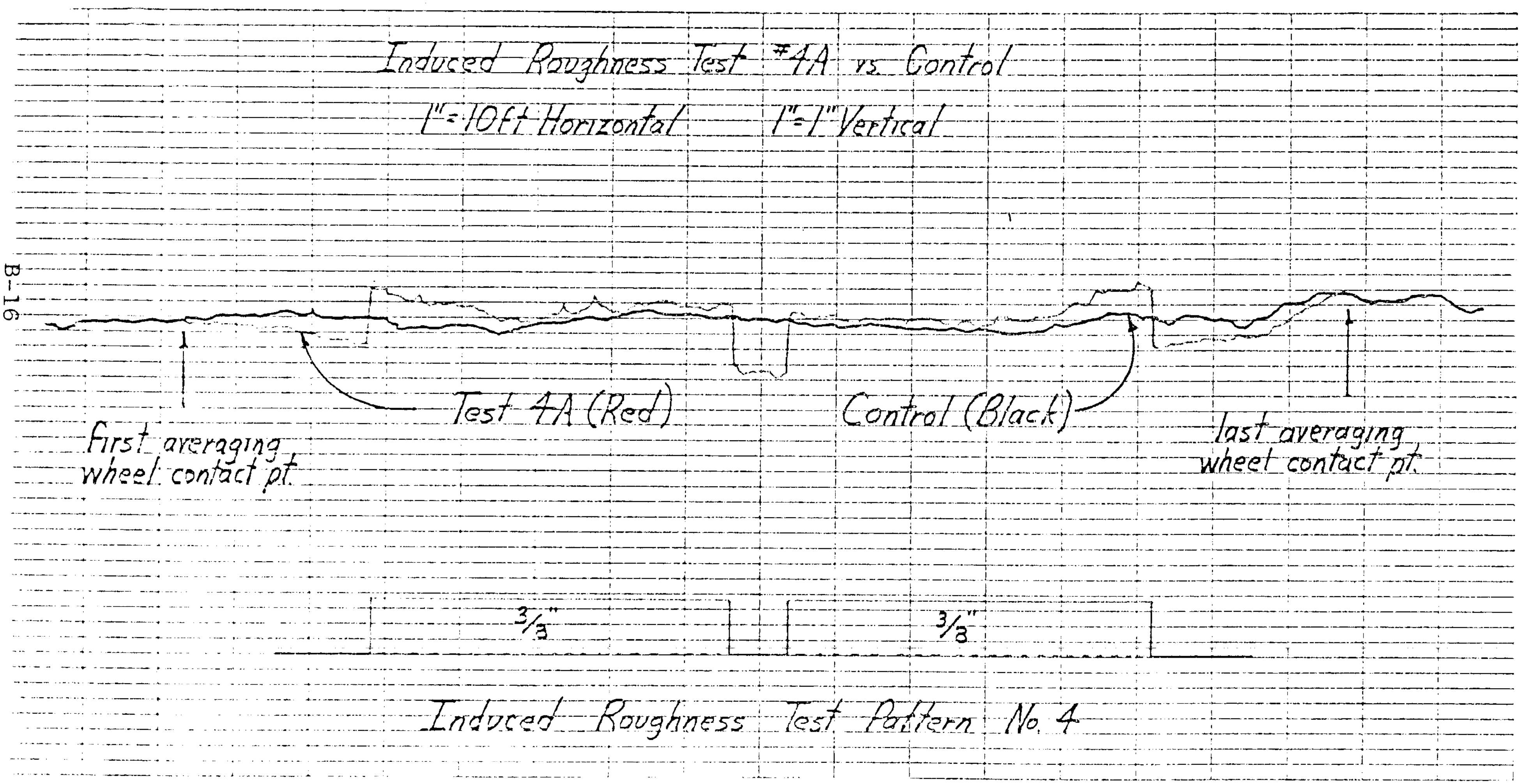


INDUCED ROUGHNESS TEST PATTERN NO. 6

induced "bumps" which were shown graphically to be approximately 1/2 foot wider at the bottom than they are at the top. However, in both cases the true or actual dimension is the reading taken at the high point on the graph. Each of the three tests in this group are discussed below. One of the most interesting features of test No. 4 can be seen when the "hole" is isolated from the remainder of the display. The depth of this 3/8-inch hole is then measured on the graph paper to be 0.45 inch deep, slightly more than its actual dimension. However, when plotted against the graph of the original ground at this location, the picture is further distorted from the actual condition (see Figure 13).

As the profilograph mounts the first 3/8-inch plateau with the first averaging wheel the graph begins a steady fall from the position of the actual ground until, at the point the measuring wheel encounters the plateau, it is approximately 0.2 inch below natural ground (approximately one-half the depicted height of the plateau). This is the same phenomenon described in tests No. 2 and No. 3 and is consistent with the averaging tendencies of the profilograph. Then, at the point the measuring wheel strikes the plateau the graph jumps to a point approximately 0.2 inch above normal ground. However, the plot proceeds downward from this point until, at the position where the last averaging wheel encounters the plateau, it is at almost the same position as natural ground. The plot stays at or slightly above

Figure No. 13



Induced Roughness Test #4A vs. Control
1" = 10Ft Horizontal
1" = 1" Vertical
Test 4A (Red)
Control (Black)
First averaging wheel contact pt.
last averaging wheel contact pt.
3/8"
3/8"
Induced Roughness Test Pattern No. 4

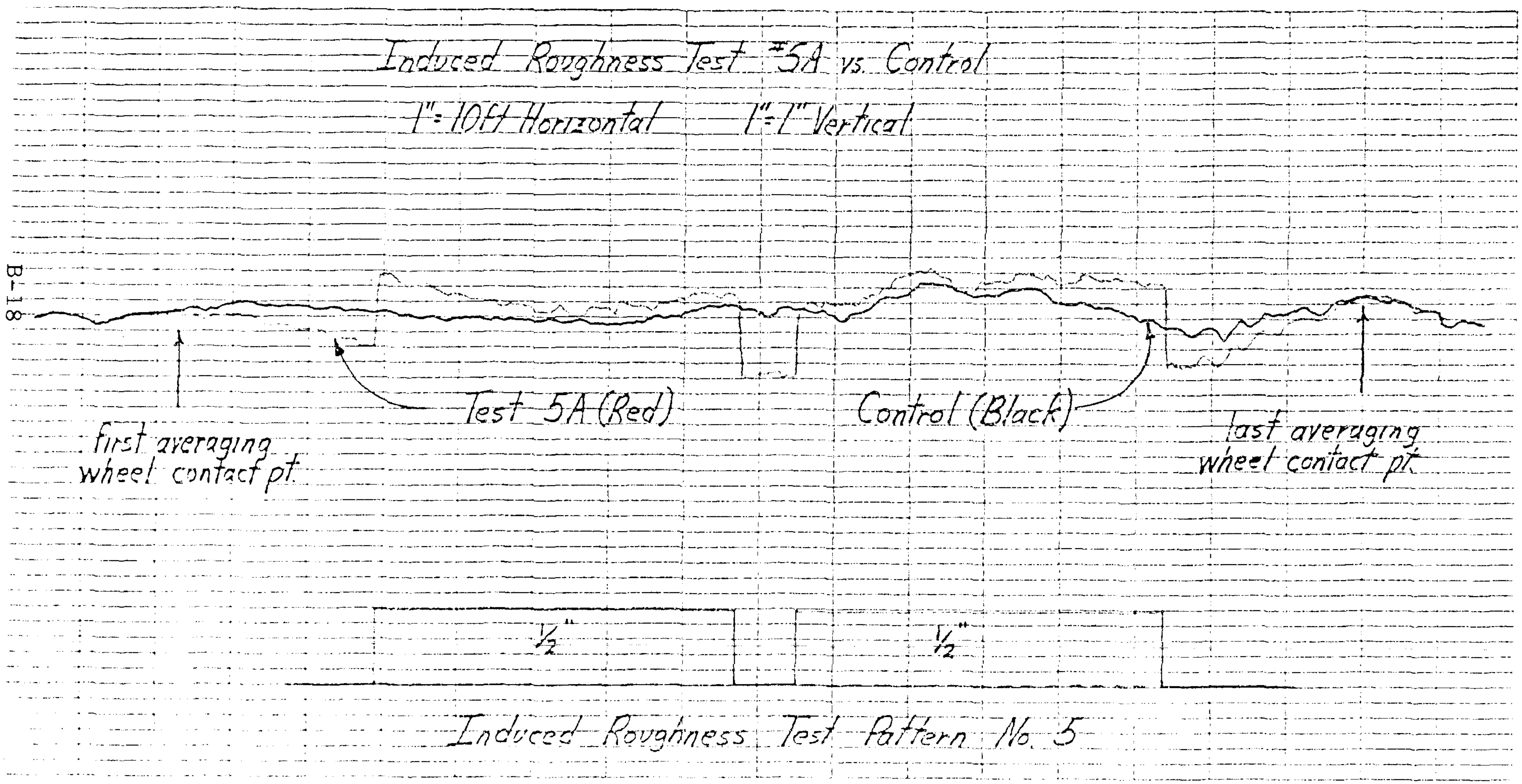
the natural ground position until the depression is encountered, at which point it falls approximately 0.45 inch to a position approximately 0.35 inch below the true location of natural ground. The plot is very nearly symetrically centered around the depression, gradually rising again to a point approximately one-half the height of the plateau as the measuring wheel leaves the last board, then dropping an equal distance below natural ground only to gradually rise to meet the true location of natural ground as the last averaging wheel leaves the last board.

The unfiltered digital readouts of the No. 4 runs average 5.9 inches of roughness. This is approximately 2.15 inches above the measured control reading even though only 0.75 inch of induced roughness was added to the course. The 0.1-inch filtered readings averaged 3.3 inches total or 1.35 inches above the control. The graphical method also yielded an answer 1.35 inches above the control.

Thus, with all three methods the actual roughness was significantly overstated, ranging from 180% to 285% of the actual value.

This test pattern, along with tests No. 5 and No. 6, was devised to simulate faulted slabs which are common to older jointed concrete pavements and "punch-outs," a type of failure most frequently associated with continuously reinforced pavements. Thus these findings, that the profilograph overstates the actual roughness present in these

Figure No. 14



Induced Roughness Test #5A vs. Control
1" = 10ft Horizontal 1" = 1" Vertical
Test 5A (Red)
Control (Black)
first averaging wheel contact pt.
last averaging wheel contact pt.
1/2"
1/2"
Induced Roughness Test Pattern No. 5

situations, should be taken into account prior to setting a specification limit for the repair and/or rehabilitation of failed concrete pavements.

Results - Test No. 5

The concept of this test was similar to test No. 4 in that it measured the response of the profilograph to a simulated faulted slab and a punch-out, the only difference being that in this test the raised plateaus were made of 1/2-inch boards rather than the 3/8-inch boards used in test No. 4. Although the graphical display of the profilograph did reflect the increased depth of the hole, it was otherwise just as described in test No. 4 (see Figure 14).

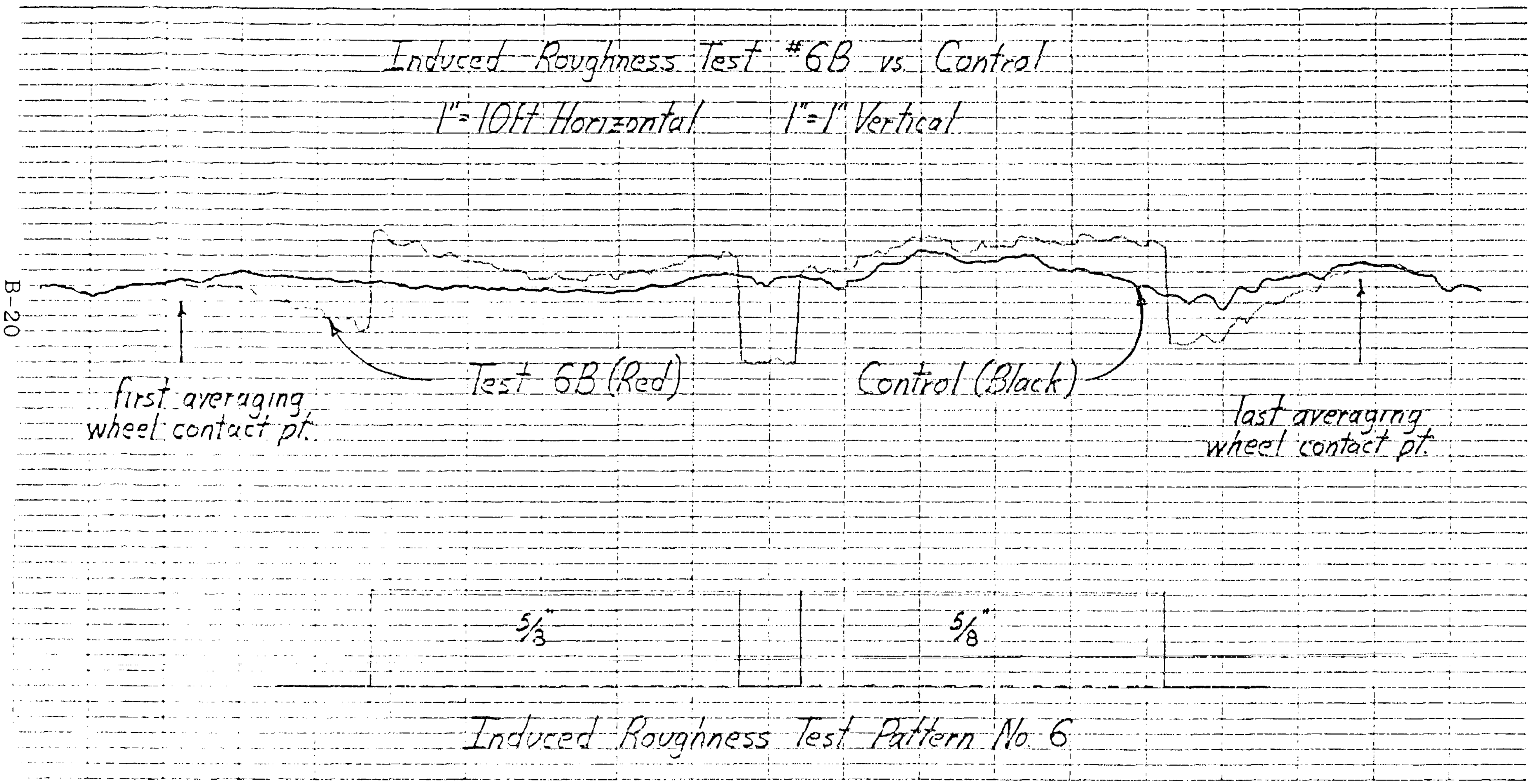
In all, a total of 1 inch of induced roughness was actually added to the control; but the unfiltered roughness readings for run No. 5 averaged 6.05 inches, approximately 2.3 inches above the average unfiltered reading of the control. The filtered digital readings were 1.7 inches above the corresponding control and the graphical calculations averaged 1.2 inches above the control.

As in test No. 4, each method significantly overstated the actual roughness added to the test course, with this difference ranging from 230% for the unfiltered digital readout to 120% for the 0.1-inch graphical filter band method.

Results - Test No. 6

This test was identical to test No. 4 and test No. 5 except

Figure No. 15


Induced Roughness Test #6B vs. Control
1" = 10ft Horizontal 1" = 1" Vertical
first averaging wheel contact pt.
Test 6B (Red)
Control (Black)
last averaging wheel contact pt.
5/3"
5/8"
Induced Roughness Test Pattern No. 6

that this time the raised platforms were constructed using 5/8-inch-thick boards. Again, the action of the profilograph was very similar to that described in tests No. 4 and No. 5. The indicated depth of the hole was approximately 0.7 inch, slightly larger than its actual 0.625-inch depth, but it is below or lower than its actual position (see Figure 15).

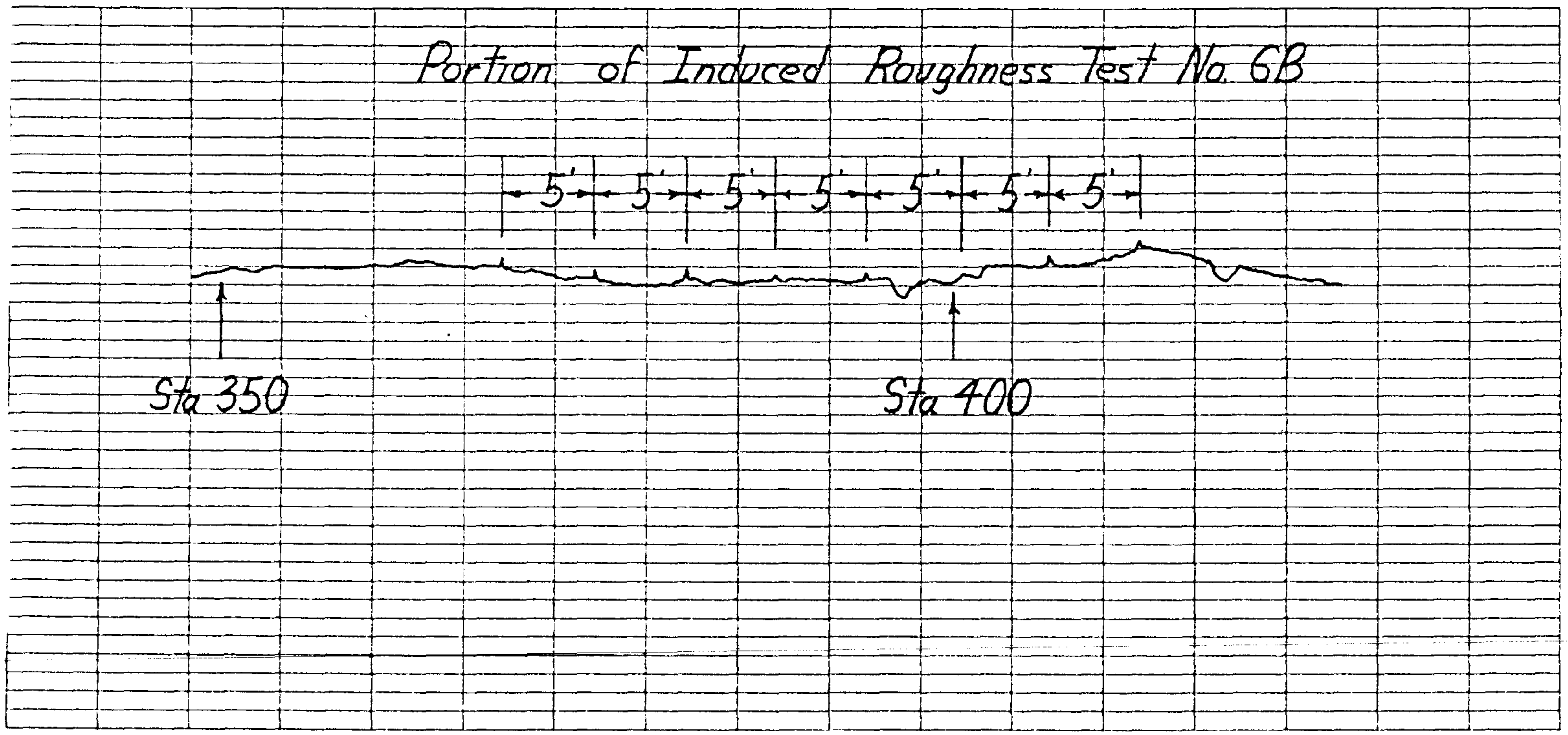
In all, a total of 1.25 inches of induced roughness was added to the test course in these runs. The unfiltered roughness increased by approximately 2.15 inches, the filtered roughness increased by approximately 1.95 inches, and the graphical calculation increased by 1.4 inches. Again, this represents an overstatement of the actual roughness ranging from 172% to 112%.

Comment

An interesting occurrence can be illustrated using the graphical display of this last test. The digital readouts for test run 6B have been noticeably increased by an object becoming fixed to the measuring wheel, and thus this test was disregarded when computing the digital averages stated above. The presence of this object can be very clearly seen by observing the graph of the 6B run beginning with station 365. At this point regular spikes begin to appear in the graph (see Figure 16).

These spikes are spaced at precisely 5-foot intervals, the exact circumference of the measuring wheel. Although the

Figure No. 16



Portion of Induced Roughness Test No. 6B cause of the spikes in this test is not known, similar spikes have been observed when asphalt-covered pebbles became stuck to the measuring wheel.

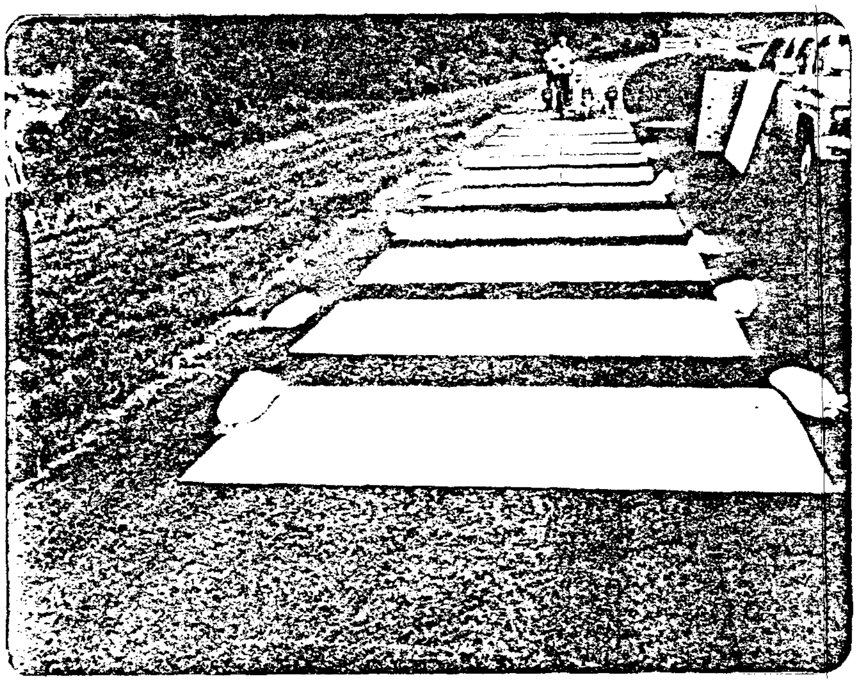
Induced Roughness Tests No. 7, No. 8 and No. 10

The purpose of these tests was to determine the impact to the profilograph which would occur when the spacing between the individual deviations was varied. In these three tests the same total inches of induced roughness and the same sequence of "bumps" were used in each case. Only the distance between the individual bumps was varied. This distance between bumps was maintained at the previously used 4 feet in test No. 7, was decreased to 2 feet in test No. 8 and increased to 8 feet in test No. 10 (see Figure 17). As explained earlier, the 4-foot spacing is thought to be representative of the most common bump frequency encountered in a normal portland cement pavement. The 8-foot spacing may be closer to that encountered in a slip form operation while the 2-foot spacing might be representative of a formed city street.

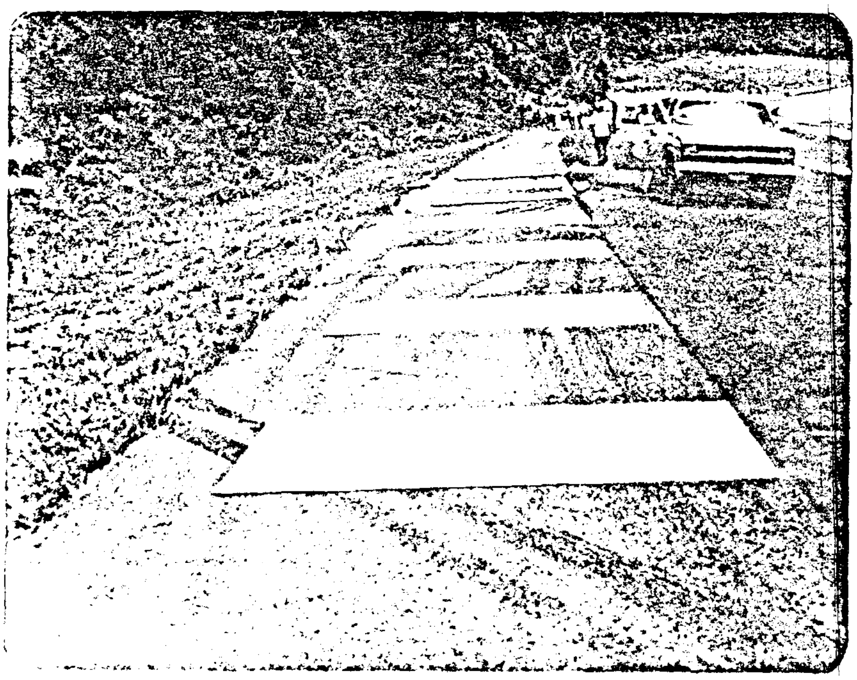
Discussion of Results

Again, the graphical outputs very accurately plotted the locations of the induced bumps. The vertical height of the bumps as shown on the graphs is also very close to the actual height of the projections but, as in other tests, is as much as 0.1 inch high.

FIGURE 17



INDUCED ROUGHNESS TEST PATTERN NO. 8



INDUCED ROUGHNESS TEST PATTERN NO. 10

In total, 4.75 inches of induced roughness was added to the control roughness in each of the three tests, yet the numerical readouts from the digital counters were quite different as shown below.

TABLE 3

DIGITAL RESULTS OF INDUCED ROUGHNESS
TESTS NO. 7, NO. 8 AND NO. 10

Run No.	Gap Size	Unfiltered Inches Above Control	% of 4.75	Filtered Inches Above Control	% of 4.75
7	4 feet	8.03	169	5.57	117
8	2 feet	8.65	182	6.55	138
10	8 feet	9.0	189	6.63	140

One interpretation of these results is that where gap size is equal to bump size the averaging characteristics of the profilograph interpret the projections as if they were a series of bumps and depressions rather than just bumps. Thus, the 1/8-inch boards are filtered out completely and the 1/4-inch boards are just barely visible above the 0.1-inch filter. The validity of this theory can be judged by examining the graphical displays when plotted against the control profile. In test No. 7 where the "bump" length is equal to the spacing between "bumps" the high and low points of the test pattern are plotted approximately equidistant above and below the actual grade line. When the "bumps" are spaced further apart as in test No. 10, more averaging wheels at any one time are on the original ground than are on the raised deviations, and thus the graphical profile shows higher projections above the original grade than below it. With the closer spacing (test No. 8) the reverse is true with the projections above the original profile being much smaller than those below it (see Figure 18).

It is only when using the filter band method that the actual value of 4.75 inches of added roughness can be closely approximated.

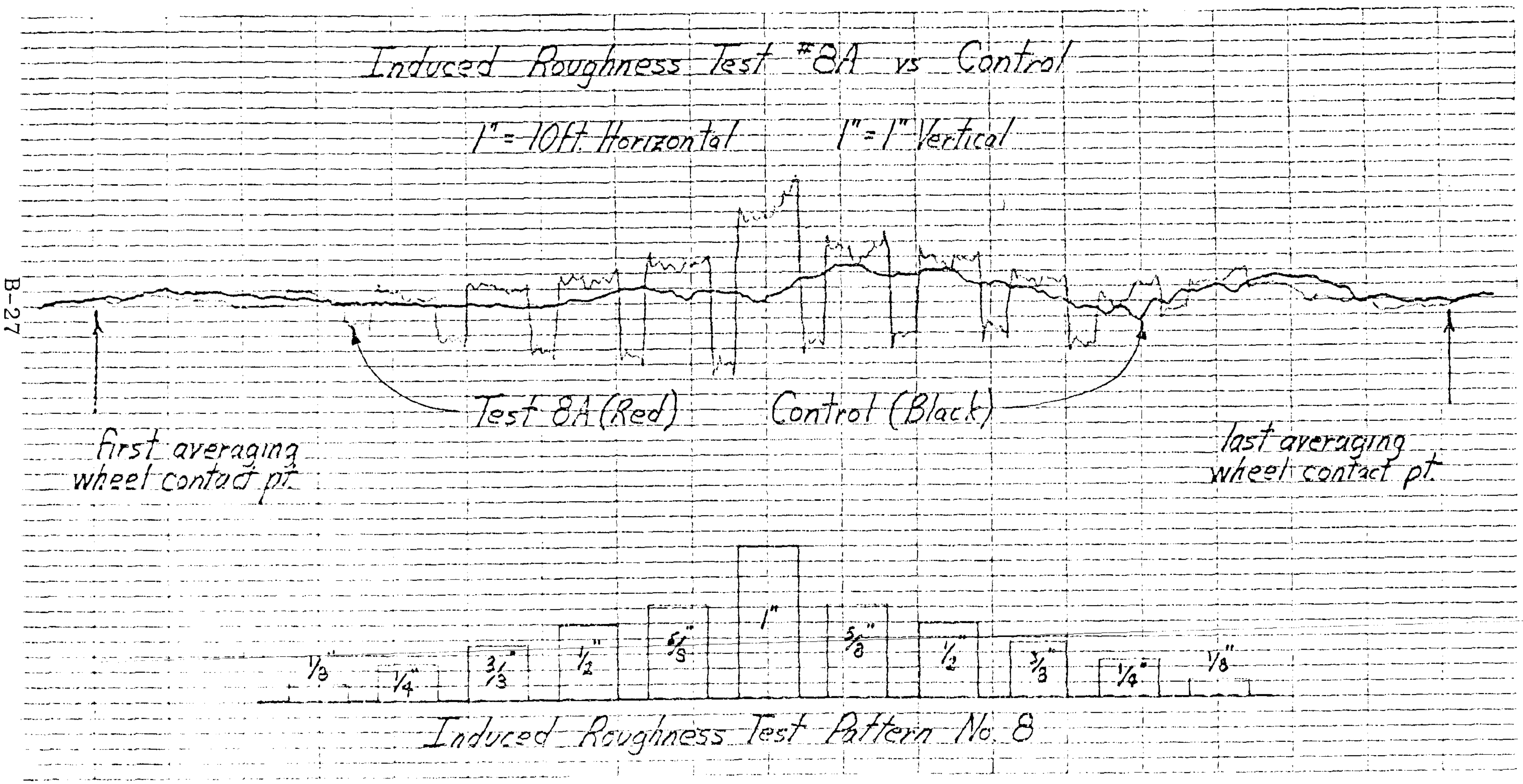
TABLE NO. 4

FILTER BAND RESULTS OF INDUCED ROUGHNESS
TESTS NO. 7, NO. 8 AND NO. 10

Run No.	Original Control	Average Total From Filter Band Inches	% of 4.75
7	1.25	4.70	99
8	1.25	4.65	98
10	1.25	4.98	105

In judging the impact of these variations as to the frequency of the deviations, it can be seen that there is very little difference in the amount of added roughness between the 2-foot spacing and the 4-foot spacing, with the filter band measurements very accurately indicating the total value of the actual roughness. However, in both the digital readouts and the filter band calculations the 8-foot spacing did produce a roughness value which was actually higher than the true figure. While this may indeed indicate a tendency toward a slight overstatement of the roughness of widely

Figure No. 18


Induced Roughness Test #8A vs Control
1" = 10ft. Horizontal
1" = 1" Vertical
Test 8A (Red)
Control (Black)
first averaging wheel contact pt.
last averaging wheel contact pt.
1/8"
1/4"
3/8"
1/2"
5/8"
1"
5/8"
1/2"
3/8"
1/4"
1/8"
Induced Roughness Test Pattern No. 8

spaced deviations, the approximately 5% difference found when using the graphical method is not statistically significant and at any rate is not large enough to warrant any special consideration of bump spacing when calculating roughness.

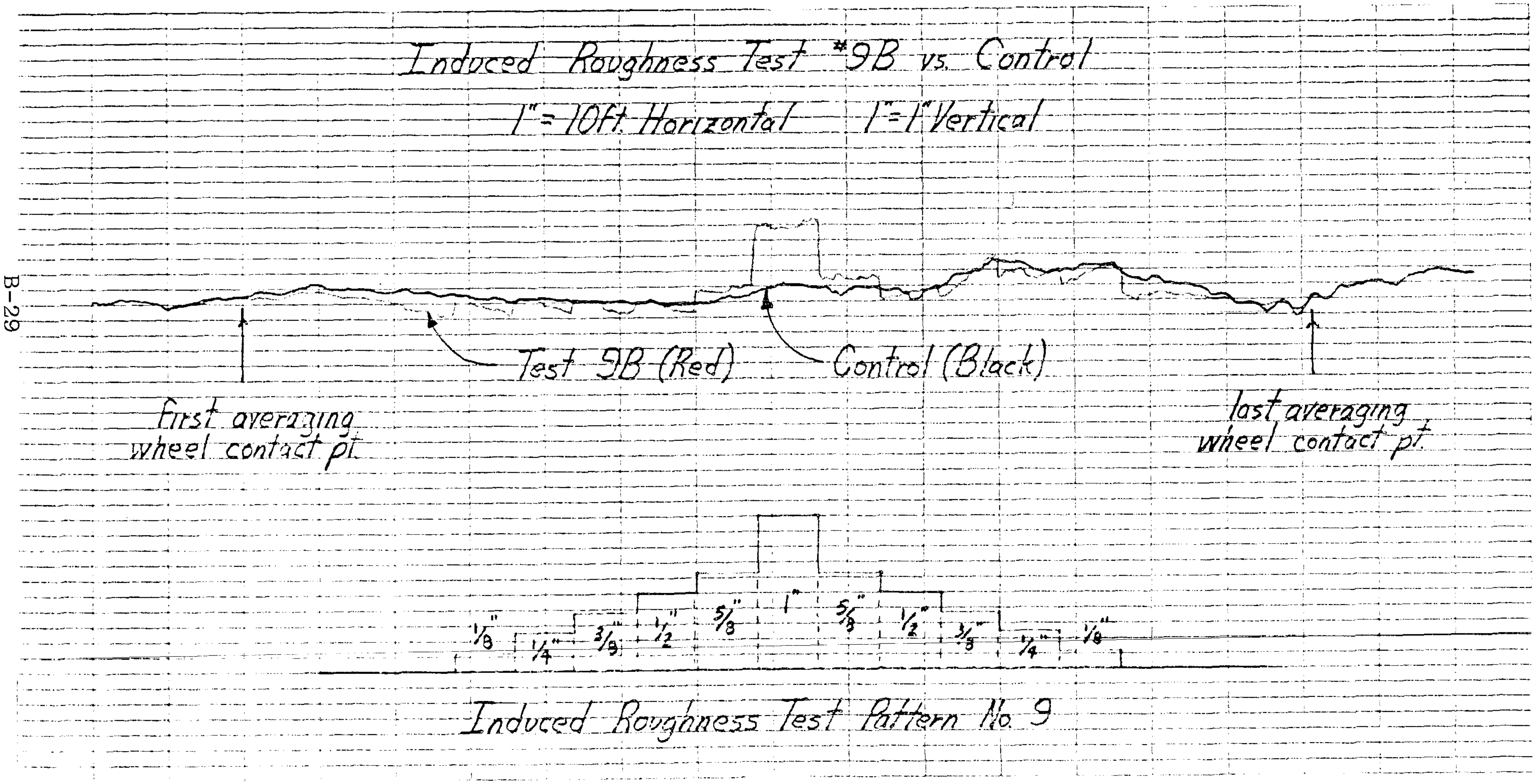
Induced Roughness Test No. 9

The purpose of this test was to determine the response of the profilograph to a very long wave length deviation. To construct this test pattern the individual sheets of plywood were laid side by side in a stepped configuration beginning at 1/8-inch thickness and proceeding through 1/4-inch, 3/8-inch, 1/2-inch, 5/8-inch and 1-inch thicknesses. The configuration was symmetrical about the 1-inch board stepping down again to the 5/8-, 1/2-, 3/8-, 1/4- and 1/8-inch thicknesses. In all, the test pattern was 44 feet long and consisted of a total induced roughness of 1 inch.

Results - Test No. 9

As usual, the graphical display very accurately located the beginning and ending points of the test pattern, showing them to be nearly exactly 44 feet apart. Because the total length of the test pattern was almost twice the length of the wheel base of the profilograph and because the 1/8-inch height of the steps was so small, it was difficult to predict the response of the profilograph. However, as is quite clearly shown on the display (Figure 19), the roughness

Figure No. 19


Induced Roughness Test #9B vs. Control
1" = 10 ft. Horizontal   1" = 1" Vertical
Test 9B (Red)
Control (Black)
first averaging wheel contact pt.
last averaging wheel contact pt.
1/8"
1/4"
3/8"
1/2"
5/8"
1"
5/8"
1/2"
3/8"
1/4"
1/8"
Induced Roughness Test Pattern No. 9

created by the 1/8-inch steps up are shown on the graph to be below the actual grade, as are the steps down. Only the 1-inch board is shown accurately, projecting 0.4-inch above the surrounding 5/8-inch boards, but the vertical position of this board is shown to be approximately 1/2-inch below its actual position.

In all, a total of 1 inch of induced roughness was added to the test strip; however, the unfiltered digital readings increased by approximately 2.3 inches while the filtered digital readings went up 1.2 inches. Using the 0.1-inch filter band, the increase is clearly understated being only approximately 0.85 inch.

As can be seen in Figure 19 with the induced roughness display of test No. 9 superimposed over the original ground display, the long wave length deviation is virtually invisible to the profilograph, the exception being, of course, the 1-inch board which in this case significantly projects above the surrounding boards.

If this display were presented to a contractor, the only corrective action indicated would be to grind approximately 0.4 inch from the center projection.

This test clearly illustrates the limitations of the profilograph when dealing with deviations which have a wave length longer than the wheel base of the machine.

The results of the entire series of Induced Roughness Tests are displayed in Table 5 and shown graphically in Figure 20. As can be seen, the three methods of determining roughness yielded widely different results for each test. However, in each case the unfiltered digital reading was the largest and the 0.1" graphical filter band reading was either the smallest or tied for the smallest. In particular it should be noted that in all cases both the unfiltered and the filtered digital readings exceeded the actual roughness. By contrast, the graphical filter band method yielded a result with an equal tendency to be either slightly above or slightly below the actual value and which in all cases was closer to the actual roughness than either of the two digital methods.

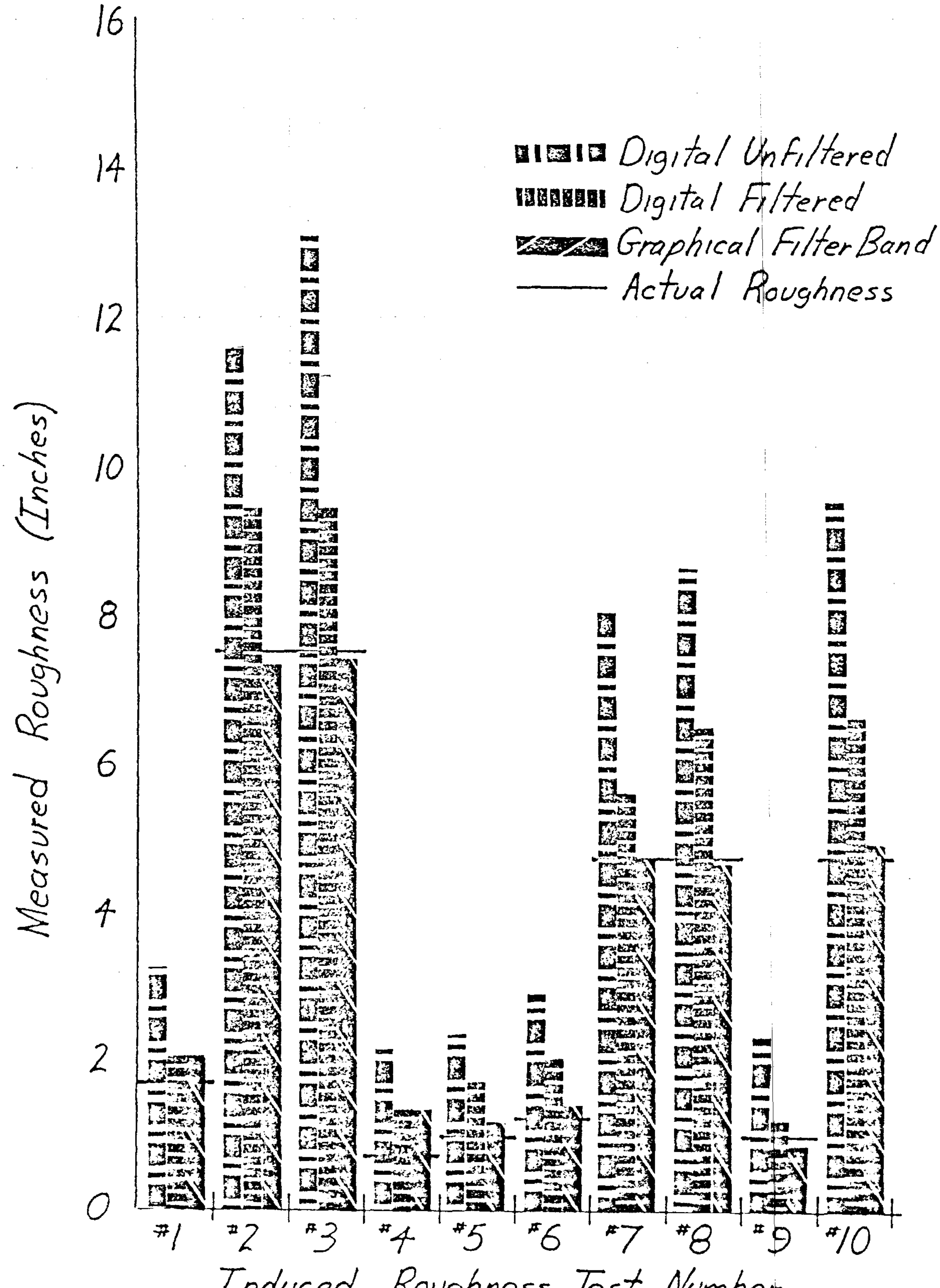
TABLE 5

SUMMARY OF INDUCED ROUGHNESS TEST RESULTS

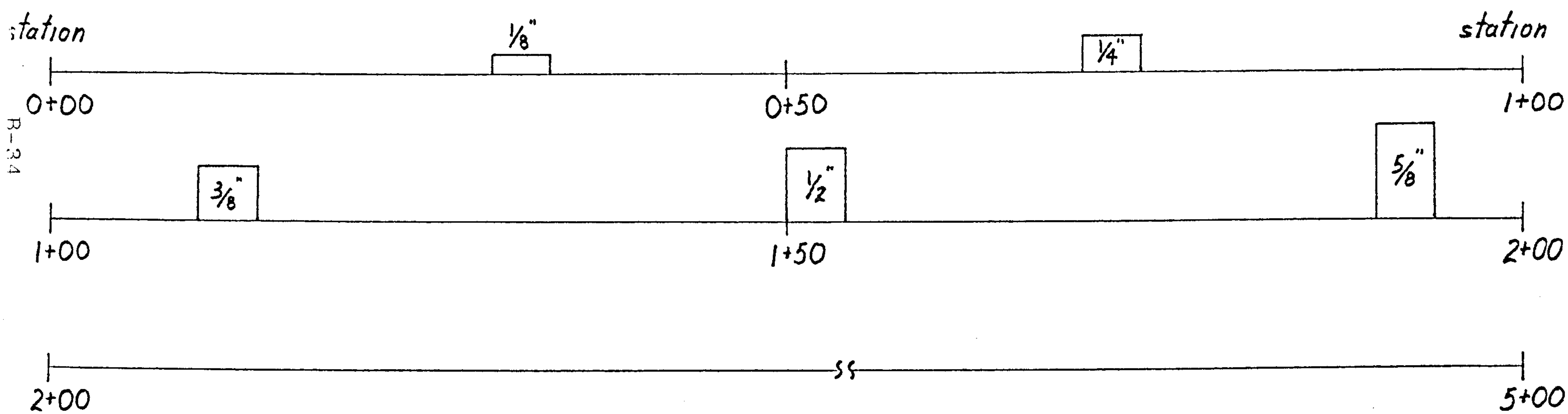
Test Number	Measured Roughness (Inches)			
		Digital		Graphical
	Actual	Unfiltered	Filtered	0.1-inch Filter Band
1A	1.75	3.2	2.1	--
1B	1.75	3.35	2.1	2.15
2A	7.5	11.4	9.85	7.15
2B	7.5	11.75	9.05	7.40
3A	7.5	12.80	9.5	7.60
3B	7.5	13.20	9.95	7.70
4A	0.75	2.25	1.45	1.45
4B	0.75	2.05	1.25	1.25
5A	1.00	3.05	1.85	1.20
5B	1.00	1.55	1.55	1.20
6A	1.25	2.15	1.95	1.40
6B	1.25	3.60	2.1	1.45
7A	4.75	8.1	5.5	4.60
7B	4.75	7.95	5.65	4.80
8A	4.75	8.95	6.65	4.75
8B	4.75	8.35	6.45	4.55
9A	1.00	2.95	1.45	0.90
9B	1.00	1.65	0.95	0.80
10A	4.75	8.35	5.85	4.90
10B	4.75	10.65	7.40	5.05

Figure No. 20

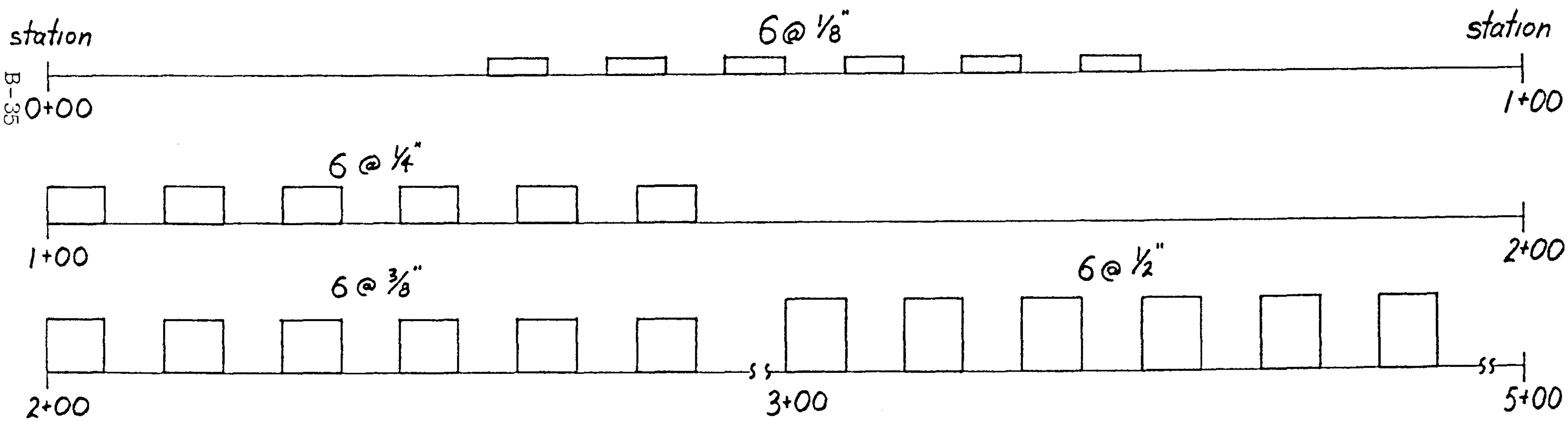
Induced Roughness Test Results



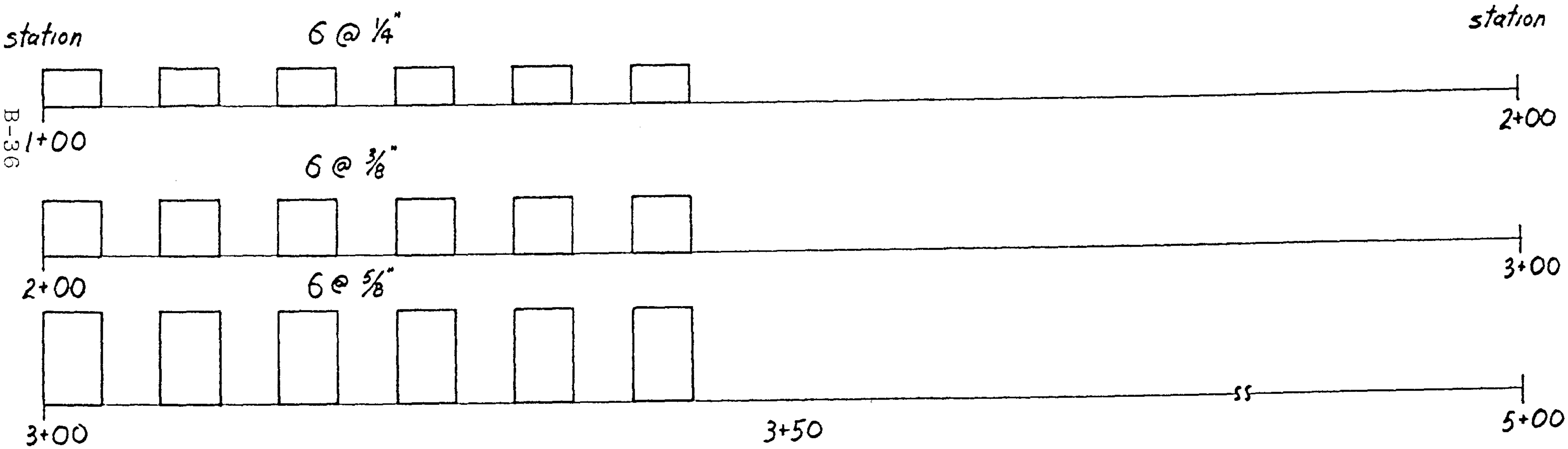
Induced Roughness Test Pattern No. 1



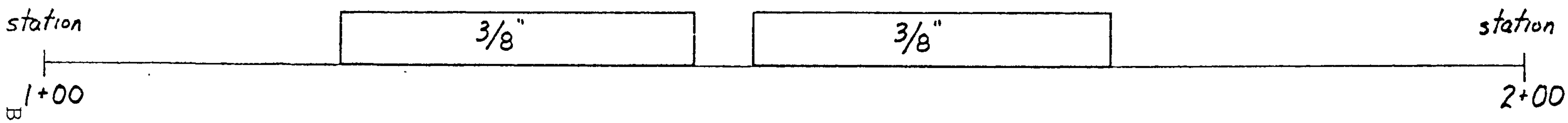
Induced Roughness Test Pattern No. 2



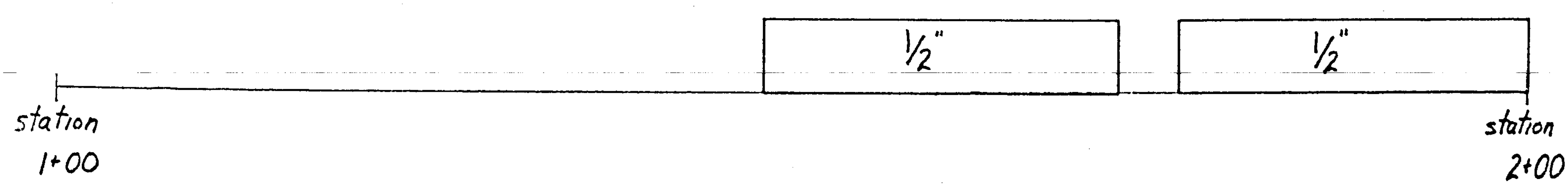
Induced Roughness Test Pattern No 3



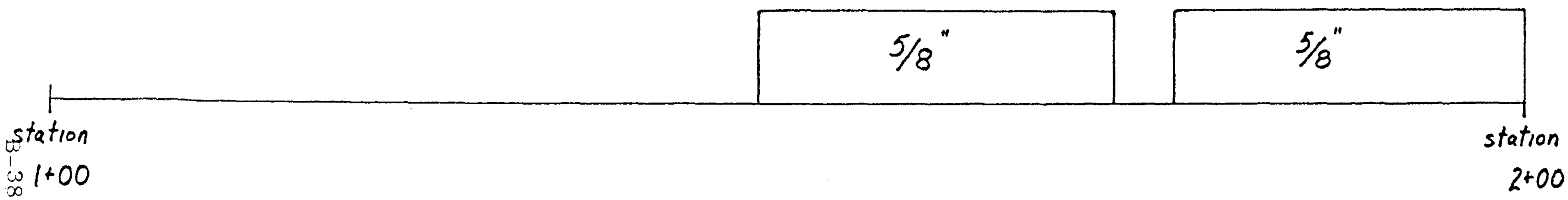
Induced Roughness Test Pattern No. 4



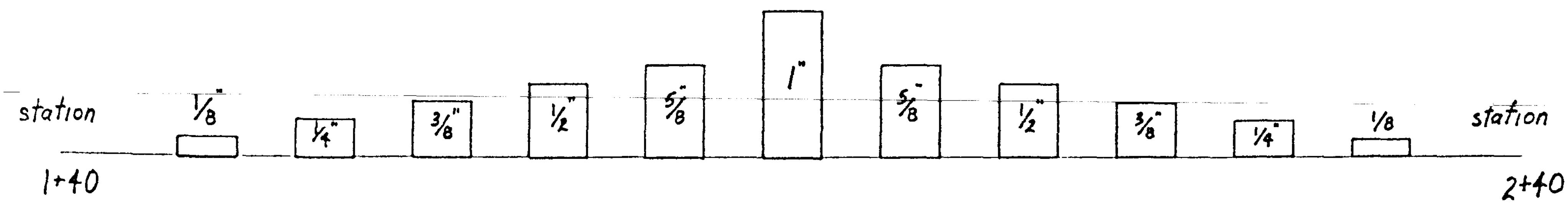
Induced Roughness Test Pattern No. 5



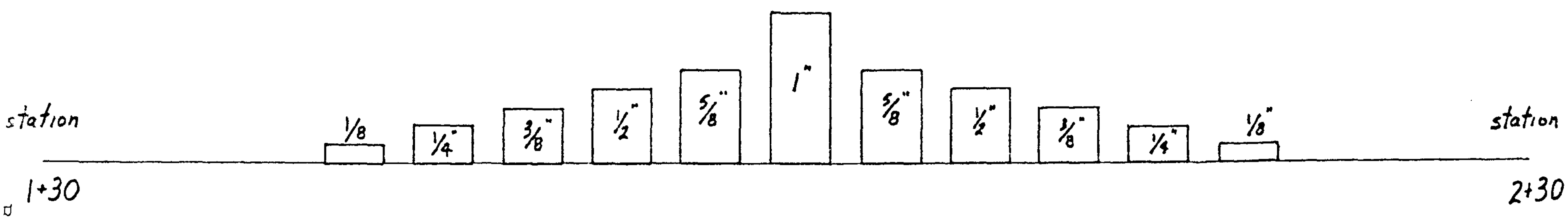
Induced Roughness Test Pattern No. 6



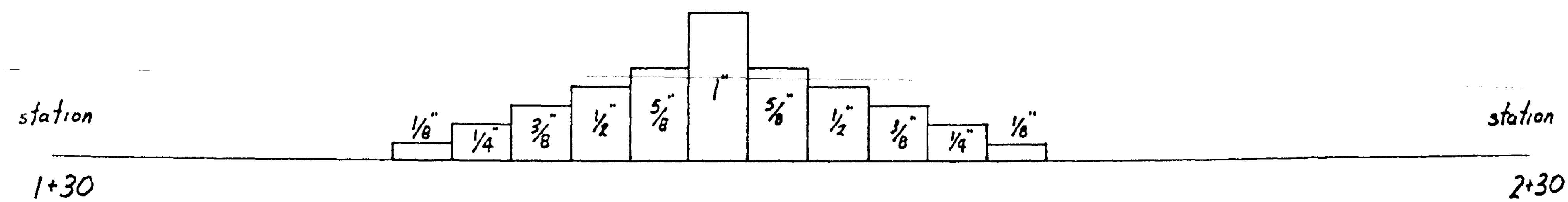
Induced Roughness Test Pattern No. 7



Induced Roughness Test Pattern No. 8



Induced Roughness Test Pattern No. 9



Induced Roughness Test Pattern No. 10