Oklahoma Department of Transportation

Materials & Research Division

Date July 9, 1998

To Byron Poynter, Construction Division Engineer

From Lawrence J. Senkowski, Assistant Division Engineer

Subject Analyzing data with the computerized Ames profilograph

In a recent investigation, the Office of Research discovered that the computerized Ames profilographs have adjustable filter controls that could significantly affect the results of a given trace. Attached you will find a report demonstrating that the **results can vary from 33 percent higher to 25 percent lower than actual roughness** when the filter setting is changed from 0 to 10. Additionally, it appears that "must grind bumps" are also filtered out with increased settings. The attached example showed a **20 percent reduction in must grind bumps at a setting of 3 and a 50 percent reduction at a setting of 10.**

Close examination indicates that the manufacturer's recommended low pass filter setting of 2.0 gives results that are 10 percent higher than the manual profilographs. Therefore, when analyzing the data, **it is recommended to keep the high pass filter at zero, increased the low pass filter to 3.0, and select "off-set" for vertical positioning of the blanking band.**

Also, it is imperative that the header information not be detached from traces that are submitted for payment.

Attachment

cc: Jack Telford
Paul Rachel
Gary Williams
File 2120-98-04

D:\WPFILES\2120_04.WPD

PROFILOGRAPH COMPARISON - Item No. 2120-98-04

At the request of ODOT Field Division III, The ODOT Office of Research conducted a comparison of smoothness test results, where testing was done with three different proifilographs. The profilographs participating in the comparison were the following. An Ames manual profilograph which had been returned to Ames Engineering, was rebuilt and computerized, and returned to Division III, The ODOT Office of Research's (new) Ames computerized profilograph, and Division IV's McCracken manual profilograph, recently transferred to them from Research. The comparison was done because of differing results from Division III's profilograph. Division III had tested Gordon Cooper Drive, in Tecumseh, with their Ames manual profilograph, which was later returned to the manufacturer to be rebuilt and computerized. When the newly computerized profilograph was returned to them, they tested the same project again. The Contractor had done some grinding since the first test, so the project was expected to be somewhat smoother. Test results from the rebuilt, computerized unit showed it to be rougher. During the June 11, 1998 comparison, the profilograph units listed tested the project with the following results.

Profilograph	Profile Index (In/Mi)	
	Run 1	Run 2
Field Division III's (rebuilt) Ames computerized unit.	16.28	16.13
Office of Research's (new) Ames computerized unit	15.12	15.17
***Field Division IV's (manual) McCracken unit**	9.5	9.5

* Interpreted by the ProScan System.

The Ames Computerized profilographs have three user-selected controls which can affect the results produced. These are 1) blanking band positioning, 2) low pass filter and 3) high pass filter.

Blanking band positioning allows the user to select how the blanking band will be placed on the profile line. The two options are "similar vertical positioning" and "off-set vertical positioning". In "similar vertical positioning" the blanking band is placed so that the end of the last band placement, for a 1/10 mi segment, is used as the starting point for band placement on the next segment. The other option, "off-set vertical positioning", places the band such that band position for each each segment is independent of adjacent segments. The "off-set vertical positioning method is similar to the method used by the ProScan system, which ODOT uses.

The low pass filter "allows the operator to filter out unwanted chatter from the trace so that a

smoother propfile will be printed and analyzed" (Ames 4000B Manual). As discussed further in this report, as settings of this filter increase, the resulting profile indexes decrease.

The high pass filter option allows the user to filter out sharp horizontal curves and vertical curves where the blanking band cannot be placed properly on a 1/10 mile length of trace due to elevation differences. Surfaces with these conditions are generally excepted from smoothness testing. Most state DOT's (including ODOT) do not use this option.

During the Gordon Cooper Drive test, both computerized units were set on "similar" blanking band positioning and had their Low Pass filters set on 2.0. The Ames Engineering representative suggested setting the Low Pass Filter on 2.0 during the class held when the computerized profilographs were delivered. "Similar" was the default blanking band position and neither profilograph operator (Research or Division III) changed it.

Although all three profilographs demonstrated acceptable repeatability, results from individual units differed widely. Ames Engineering representatives suggested checking the tapes for unusual amounts of "spiking" (caused by unfiltered vibration). The tapes showed little or no "spiking".

The McCracken manual profilograph which participated in the comparison is the oldest profilograph owned by ODOT. It is close to the point where it will have to be rebuilt if it is to continue in use. Because of this, and because it's results differed considerably from the two computerized units, it was decided that it should be checked on a track it had tested earlier. This was done on a track on U.S. 69 which was first used during a profilograph operator's course in 1995. The track has been tested various times since then. It was last tested five months ago. Results approximately agreed with previous tests and were considerably closer (between the two units) than during the Gordon Cooper Drive tests. Test results are shown below.

Profilograph	**Profile Index (In/Mi)**	
	Run 1	**Run 2**
Office of Research's (new) Ames computerized unit	17.70	17.73
***Field Division IV's (manual) McCracken unit**	16.2	16.4

* Interpreted by the ProScan System.

John Klatt of Ames Engineering had agreed (by phone) to try to meet with Research and Division III profilograph operators on this problem during his next trip to Oklahoma. On 6-25-98, He delivered an Ames Computerized profilograph to the McAlester Residency and met with Division III personnel, then came to the U.S. 69 test site where he met Office of Research personnel. He indicated the

following actions could be taken to get closer agreement between Ames computerized profilographs and other units.

1. Blanking band position should be changed from "similar" to "off-set".

2. The low pass filter setting can be changed.

When a roadway or bridge has been tested with an Ames computerized profilograph, the data collected (the profile) can be re-analyzed, using different low pass filter settings, as long as the data is still in the computer memory. Blanking band positioning, filter settings, etc. can be changed and the data analyzed using the changed settings, without having to test the roadway or bridge a second time. Parameters used during each analysis are automatically printed as a "header" on the tape where test results and the profile resulting from the analysis are printed (Figure 1).

Data from the U.S. 69 test strip was analyzed with the blanking band position changed from "similar" to "off-set". This blanking band position was used on all re-analyses. Analysis was done using various low pass filter settings, to determine which would give results with the closest agreement to those from the McCracken manual profilograph. Re-analysis was also done with two settings (0.0 and 10.0) which were outside the range where the two units were generally in agreement (within +/- 10 percent). This was done to see what the effect of these settings would be on results.

Results of re-analyses of the U.S. 69 Test strip data, with low pass filter settings from 0.0 to 10.0 are listed below. Profile lines generated at each setting were visually inspected. At the 0.0, setting, there was noticeable "spiking" present on the profile line. None of the profile lines generated at other settings contained obvious spikes. However, as the settings became higher, more sharp breaks in the profile line, and short-length bumps appeared smoothed or filtered out. As filter settings became higher, the number of must-grind bumps identified was lowered as increased filtering was applied to short-length bumps and low spots. Figure 3 shows the profile lines generated at filter settings of 0.0, 2.5 and 5.0.

Profile Indices Determined by Office of Research Ames Computerized Profilograph, Low Pass Filter Settings between 0.0 and 10.0

Low Pass Filter Setting	0.0	2.0	2.5	3.0	4.0	5.0	10.0
Profile Index (Inches/Mile)	21.31	16.54	16.10	15.79	15.05	14.61	12.70
No. of Must-Grind Bumps	19	15	15	15	13	11	9

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Ames Profilograph
     Software Version 3.298
       SERIAL # 400398

Contractor =
Operator = jrryuilliams
District = 3
Route # = 0
Pavement # = conc
Pass # = 1
File = JR1FILE1.PDF
Band Placement = Linear regression
Band Positioning = Off-Set
Band Width(in.) = 0.20
Bump Height(in.) = 0.40
Bump Width(ft.) = 25.00
Reduction Length(ft.) =  528
Low pass Filter(ft.) = 5.00
High Pass Filter(ft.) = 0.00
Scallop Rounding(in.) = 0.01
Horizontal Scale = 300 To 1
Paper Factor =1.800
Vertical Calibration = 1.353
Horizontal Calibration = 1.422
Bump Detection = On
Dip Detection = Off

     --Collection Time and Date--
  Time: 09:32:42     Date: 06-11-1998

      --Printed Time and Date--
  Time: 08:09:52     Date: 06-30-1998
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Figure 1 **"Header" Information Printed on Each Tape by the Ames Computerized Profilograph**

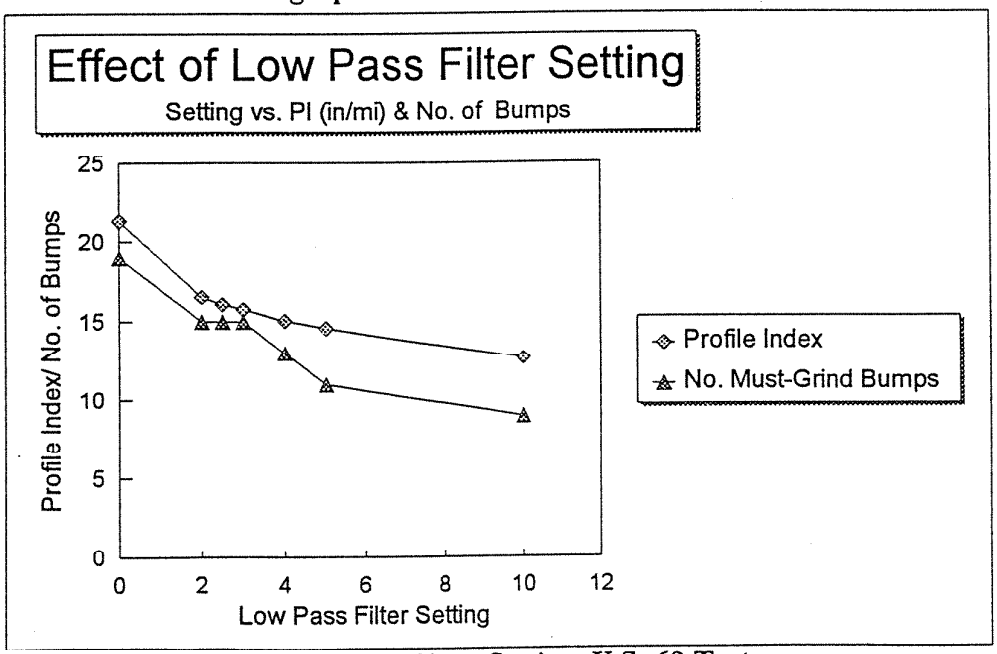

Figure 2 **Effect of Low Pass Filter Setting, U.S. 69 Test**

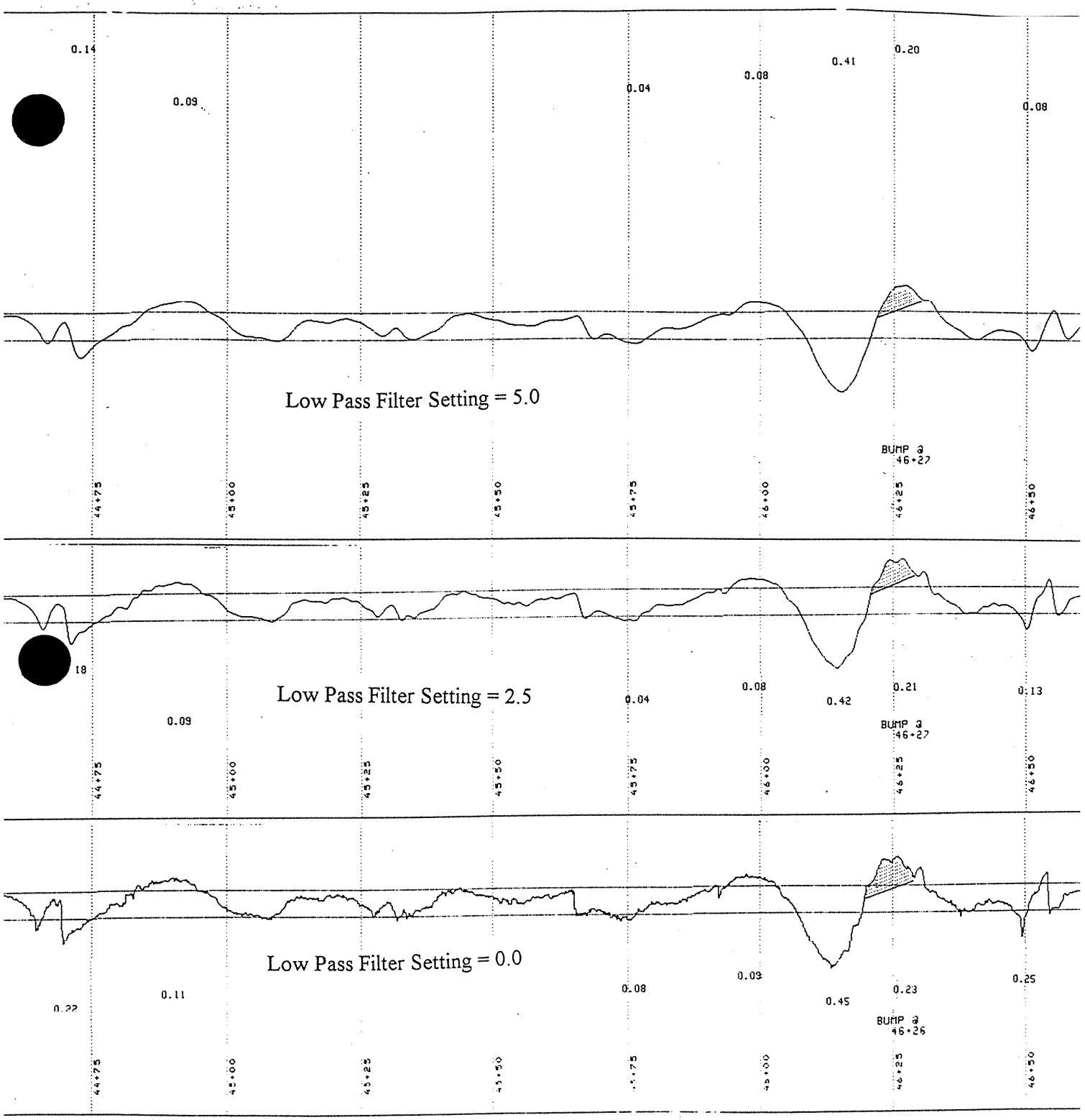

Figure 2 Section of Profile Line Generated by Research's Ames Computerized Profilograph with Low Pass Filter Settings of 0.0, 2.5 and 5.0

On the U.S. 69 test strip, a low pass filter setting of 2.5 resulted in the Ames computerized unit producing a profile index of 16.10. This agreed reasonably well with the result produced by the McCracken manual unit (interpreted by the ProScan System). The average of the two profile indices from the two tests by the manual unit was 16.30

Fortunately, data from the project where the original comparison was done (Gordon Cooper Drive, Tecumseh) was still in memory on the Office of Research Ames profilograph computer. Re-analyzing it with "off-set" blanking band positioning and various low pass filter settings produced the results summarized below. On this re-analysis, the first filter setting tried was 3.0, reasonable agreement with the manual unit was reached with a setting of 5.0. With this setting the Ames computerized unit produced a profile index of 9.33. Two Tests by the McCracken Manual unit, interpreted by the ProScan System, resulted in a profile index of 9.5 on each of the two tests. Discussion by telephone with an Ames Engineering representative indicated that 5.0 is the low pass filter setting most likely to produce results agreeing with those from manual profilographs, interpreted by ProScan.

Profile Indices Determined by Office of Research Ames Computerized Profilograph, Low Pass Filter Settings between 3.0 and 5.0

Low Pass Filter Setting	3.0	4.0	5.0
Profile Index (Inches/Mile)	10.60	10.15	9.33

Obviously, the low pass filter setting on the Ames Computerized profilograph, required to reach a reasonable agreement with the McCracken manual profilograph is not the same for all surfaces tested. Several variables may determine the filter setting required. Some possibilities are; length of path tested, roughness of the path tested, length of bumps and low spots, surface finish, and speed of the profilograph during testing. Information developed during this comparison indicates that higher (low pass) filter settings tend to produce lower profile indices, for the same path tested. This may cause a situation where a Contractors claims the low pass filter was set too low, causing a high reading.

Results of the U.S. 69 tests are tabulated by segment for each re-analysis in the Appendix attached. Inspection of the profile plots indicates that disagreement between the two profilographs by individual segments is due mainly to distance calibration differences. This occurs where both measure the same bumps and low spots, but don't put them in the same segments due to differences in horizontal distance measurement.

Conclusions

1. To get results on the Gordon Cooper Drive project which (reasonably) agree with those from the McCracken manual profilograph, the smoothness test data should be analyzed using the following parameters; Blanking band position = "Off-set" and Low pass filter setting = 5.0.

2. Low pass filter settings required to produce results which reasonably agree with manual profilographs are not the same for all projects tested.

3 Since higher (low pass) filter settings tend to lower the profile index produced, further comparison should be done to determine settings which are most likely to produce profile indices agreeing with results from manual units. The settings identified should then be specified (required during acceptance testing).

4. The "header" information, which is automatically printed at the beginning of the profile tape from Ames Computerized Profilographs, should be a required part of any tapes (from this type of profilograph) used to determine smoothness for acceptance purposes. The "header" lists all parameters used to analyze the data, including filter settings and type of blanking band positioning used.

Gary Williams
July 9, 1998

Appendix, Profilograph Test Results by Segment, U.S. 69 Tests Analyzed at Various Low Pass Filter Settings

McCracken Manual Profilograph

Track1

Segment	Length	PRI (In/Mi)
1	0.100	12.0
2	0.100	1.5
3	0.100	2.5
4	0.100	7.5
5	0.100	17.0
6	0.100	30.0
7	0.100	22.0
8	0.100	29.5
9	0.089	24.7
Total Avg.		16.2

Track 2

Segment	Length	PRI (In/Mi)	Avg. PRI
1	0.100	12.0	12.0
2	0.100	1.0	1.2
3	0.100	2.5	2.5
4	0.100	14.0	10.8
5	0.100	12.0	14.5
6	0.100	31.5	30.7
7	0.100	24.5	23.2
8	0.100	28.0	28.7
9	0.087	23.0	23.9
Total Avg.		16.4 Total Avg.	16.3

Ames Computerized Profilograph

L.P. Filter=0.0

Segment	Length	PRI
1	0.100	14.8
2	0.100	2
3	0.100	2.4
4	0.100	6.8
5	0.100	26.4
6	0.100	34.5
7	0.100	35.2
8	0.100	35.5
9	0.106	33.5
Total Avg.		21.31

L.P. Filter=2.0

Segment	Length	PRI
1	0.100	11.6
2	0.100	0.7
3	0.100	2
4	0.100	4.6
5	0.100	21.3
6	0.100	26.1
7	0.100	29.4
8	0.100	26.1
9	0.105	27.9
Total Avg.		16.54

Ames Computerized Profilograph

L.P. Filter=2.5

Segment	Length	PRI
1	0.100	11.4
2	0.100	0.7
3	0.100	2.0
4	0.100	4.3
5	0.100	21.2
6	0.100	25.6
7	0.100	27.9
8	0.100	25.6
9	0.106	25.6
Total Avg.		16.1

L.P. Filter=3.0

Segment	Length	PRI
1	0.100	11.0
2	0.100	0.6
3	0.100	2.0
4	0.100	4.2
5	0.100	20.8
6	0.100	24.6
7	0.100	28.0
8	0.100	25.0
9	0.106	26.6
Total Avg.		15.79

L.P. Filter=4.0

Segment	Length	PRI
1	0.100	10.7
2	0.100	0.6
3	0.100	2.0
4	0.100	3.8
5	0.100	20.2
6	0.100	22.9
7	0.100	26.9
8	0.100	23.9
9	0.106	23.9
Total Avg.		15.05

L.P. Filter=5.0

Segment	Length	PRI
1	0.100	10.6
2	0.100	0.3
3	0.100	1.9
4	0.100	3.8
5	0.100	19.7
6	0.100	21.8
7	0.100	26.5
8	0.100	23.2
9	0.106	23.3
Total Avg.		14.61

Ames Computerized Profilograph

L.P. Filter=10.0

Segment	Length	PRI
1	0.100	9.9
2	0.100	0
3	0.100	1.3
4	0.100	1.6
5	0.100	18.1
6	0.100	19.4
7	0.100	24
8	0.100	20.3
9	0.106	19.3
Total Avg.		12.7