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(for Materials & Geotechnical Branch)   Date: July 14, 2011

MIT-Scan-2
Evaluating Dowel Bar Placement

This Bulletin is not meant as operating instructions for the MIT-Scan-2, but rather a supplement to those included with the device. This bulletin contains useful tips on operating the device as well as transferring the data into a format that coincides with CDOT 412-13.

1. SETTING UP THE MIT-SCAN-2 DEVICE

1.1 Ensure that the pavement surface to be scanned is well swept and free of all debris.

1.2 MagnoNorm 4.2 is installed on the Pocket PC (CASSIOPEIA). The program is started by double clicking the program icon on the desktop. Note that MagnoNorm might not work properly when the Bluetooth connection with the measuring device is not established. Therefore the proper practice is switching the MIT-SCAN2-BT on after you start MagnoNorm. The user interface of MagnoNorm includes four tabs: SETTINGS, MEASUREMENTS, MAP & RESULTS.

1.3   SETTINGS

- Dowel bar type
- Location of the Measurement
- Lane and Measuring path
- Plan (assumed bar offset, bar spacing and nominal bar depth)
- Units (metric of imperial) - The MagnoNorm program does not accept decimals or fractions – so you will need to have your units set to metric. You can convert them back to Imperial Units when you transfer the data to the desktop computer.

1.4   MEASUREMENTS

- After clicking the Start, the measurement device should be pulled with a maximum speed of 2 feet/second along the joint. If the device moves too fast, the number of data samples decreases, so does the accuracy of the measurement. During the measurement, the progress of the measuring path is monitored. The current measuring values of the five sensors are displayed in a dynamic bar diagram.
- The operator of the Pocket PC should not go too far away from the measuring device; this may interrupt the Bluetooth connection. If the distance is too far, a continuous beep signal will warn the operator. Under normal conditions, a distance of 35 feet ensures a proper connection.
- Either reaching the specified lane width or pressing the Stop button or quickly moving the device backwards will stop the measurement. Moving the device backwards can be helpful in the case that the Bluetooth connection is interrupted for some reason which makes the manual termination of the measurement impossible
- After the measurement the recorded data is saved as an hdf-file. A folder will be created on every new measuring day in the directory \FlashDisk\MIT-SCAN-2 Data. The name of the folder indicates the date of the measurement. It uses a format of "yr_mm_dd.hdf". The name of the measuring file uses the

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format of "yymmddHHMMI.hdf", where "I" is an index number. This enables the device to perform multiple measurements within a minute. For instance 08081504380.hdf means that the measurement was the first measurement at 04:38 on the 15th of August 2008, while 08081504381.hdf was the second measurement in that minute.

1.5   MAP

The color map gives a visual impression of the bar positions. Areas of strong measuring signals are red; areas of weak measuring signals are yellow. The color map can be displayed in three different scaling levels. Thus, the bars are well recognized even for different signal strengths (for instance for different depths of dowel bars). Three different levels are selected by the keys 3, 6, and 9. The selection of the scale level influences also the height of the bars in the bar diagram which is displayed during the measurement.

1.6   RESULTS

- The dowel positions are shown in a table. The table includes, besides the dowel index (IDX), the following parameters:
  o   Position along the measuring path (x)
  o   Depth (zo)
  o   Side shift (dy)
  o   Horizontal misalignment (dx)
  o   Vertical misalignment (dz)

- The information box allows a quick view on different parameters of the current measurement. It includes: the name of the measuring files, date and time of the measurement, the location of the measurement, the selected bar type.
- Two buttons are available in this tab, Continue and Repeat. Continue goes to next joint measurement – and the station and joint number will increment automatically. Repeat means that the last measurement is deleted and another measurement will be conducted on the same joint.

2. TRANSFERRING DATA TO A DESKTOP COMPUTER

2.1 The MIT data needs to be manually copied to the Mini-SD card on the Pocket PC. Eject the Mini-SD card on the Pocket PC – placing it in a SD Card Reader, connecting the reader to the Desktop PC and transferring the files using Windows-Explorer. You can find MIT data in the following folders on the Pocket PC:

- Measuring files (hdf): \FlashDisk\MIT-Scan-2 Data
- Par.-files (cpf): \My Documents\MIT-Scan-2 Parameters
- Program file: \ProgramFiles\MagnoNorm

3. MAGNOPROOF

3.1 The program *MagnoProof* is used for exact analysis, visualization and documentation of measurements of the device MIT-SCAN2-BT on a Desktop PC.

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3.2 *MagnoProof* includes two main windows. The map in the **Color map** window offers a graphical presentation of the measured signals. It is an illustration of the dowel bar positions. (Figure 1).
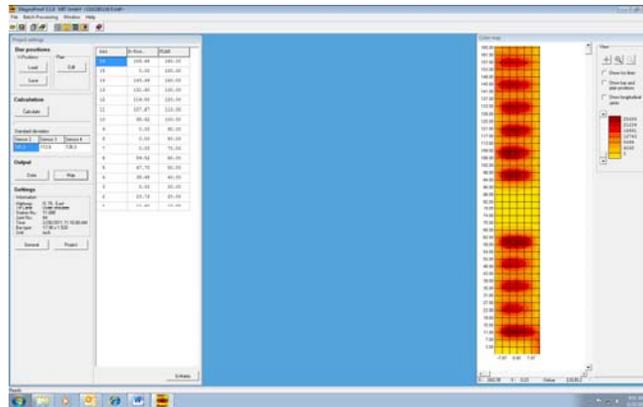

Figure 1

3.3 The positions of the bars are shown as well as their desired positions in the window **Project settings**. Here, the operator can perform different actions to control the current project: Editing and saving the dowel position plan, the correction of bar positions, changing different settings, the computation of all bar parameters and the output of the results.

When the file is opened, the dialog box **Project settings** (Figure 2) is opened, where the operator can changed the settings of the current measurement. The settings in the section location are the parameters that are input during the measurement process into the program *MagnoNorm*. The dialog box gives the opportunity for correcting wrong inputs.

Figure 2

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In one combobox the operator can select the type of dowel bar that was measured. In this way, the operator has the opportunity to correct a wrong bar type that was chosen during the measurement. In the combobox, the user will find a list of bar types, the parameter files of which are saved in the folder **Parameters** in the **MagnoProof** directory. The location data and the bar type data are included into the measurement file. The parameters indicated in the box are used for actual evaluation of bar positions. If the user clicks the checkbox Save in hdf file, then this information is stored in the hdf file.

In the **Exclude from analysis** section, check the *First bar* and *Last bar*. Specification states "Due to potential magnetic interference from tie bars, dowel bars located within 15 inches of a tied joint shall not be included in the evaluation.

3.4 In addition to the parameters included in the loaded hdf-file, there are further settings that can be changed. The user can edit them in the **General settings** (Figure 3) dialog box, which can be opened with a button in the window Project control. Here, you can choose the directory, where all output files will be saved or decide whether missing bars, which are set in the plan, are numbered or not.
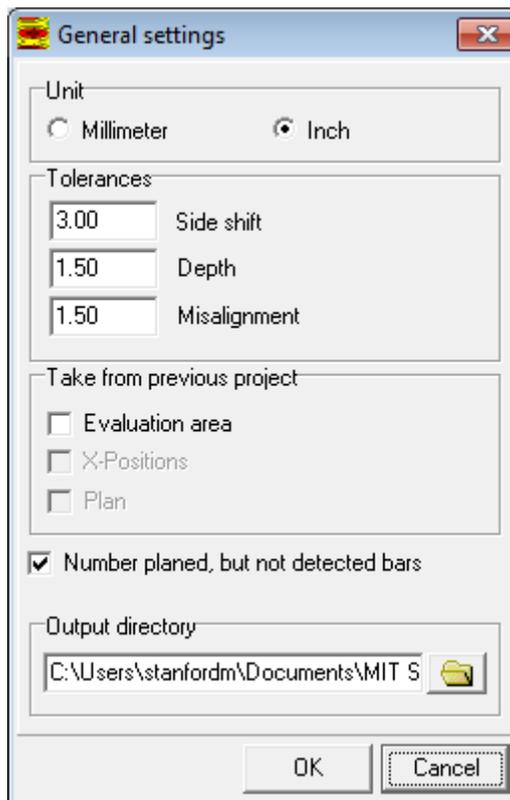

Figure 3

Furthermore, the operator can choose whether the output unit will be millimeters or inches. The user can set tolerances here, depending on the prescribed tolerances for the project.

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Typically, a series of joints are often very similar one to another. In such a case, the user can avoid loading or setting the bar positions or the evaluation area by taking the values of the previous project. When the user selects this option, the values of the previous project are kept, while a new file is loaded as long as the program is not closed. Keeping the position values is only possible, when the evaluation area is constant, because positions have to be recomputed after changing the evaluation area.

3.5 The batch processing **Calculate** offers the opportunity to evaluate a selection of measure files in one step. The bar position of a day's work can be computed without much effort and in a fraction of the time that was needed so far.

The dialog box **Batch Processing**: Calculation can be opened in the toolbar or the in the main menu **Batch Processing**. (Figure 4)
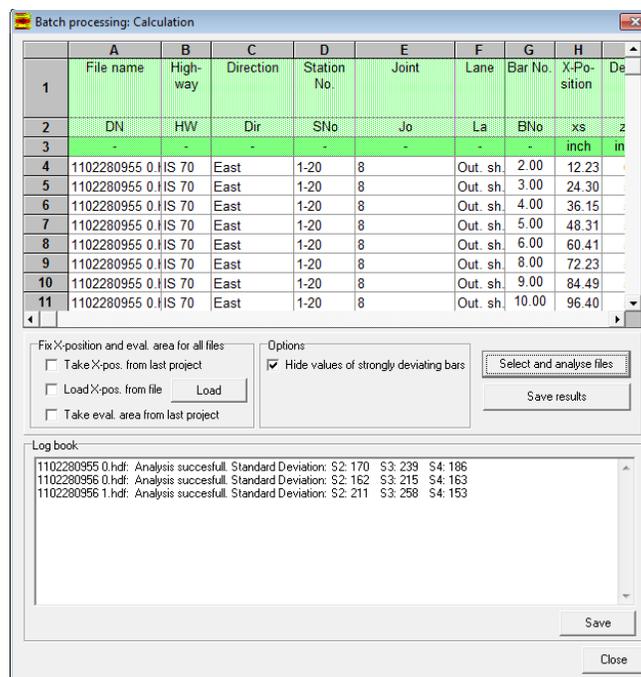
Figure 4

The evaluation starts after pushing the button Select and analyze files. A file selection dialog box appears where the files to be evaluated are selected. After finishing the selection, the evaluation process for all selected files starts. The results are written into a single Excel table. Similar to the data sheet and the graphical output and for the same reasons, result values that deviate strongly from the desired positions, can be replaced by asterisks.

There are different options for complicated bar positions where the manual editing of the project (inserting & deleting bars) is necessary.

Dowel bars in joints, inside the same road section often have very similar positions. This gives the opportunity to take bar positions and the borders of the evaluation from a manually edited project. This way, the user can avoid

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doing the same work steps again and again. The operator can simply take the parameters from the project that was evaluated, before the batch processing was started, or the user can save the bar positions and load them at the beginning of the batch processing.

When bar positions are complicated, the user should not rely blindly on the results of the batch processing because it is not always a substitution for a careful manual evaluation.

3.6 Using the **Map** button, the **Graphical output** dialog box is opened (Figure 5). The graphical display of the results includes the color map, a representation of bar positions and a summary of the results similar to the **Quick Check** table. This summary can be printed and saved as jpg-images and the file names are built from the station number and the hdf-file name. In addition, there is a suffix which represents the number of the sheet. The directory that the file is saved to, can be set in the **General setting** dialog box.
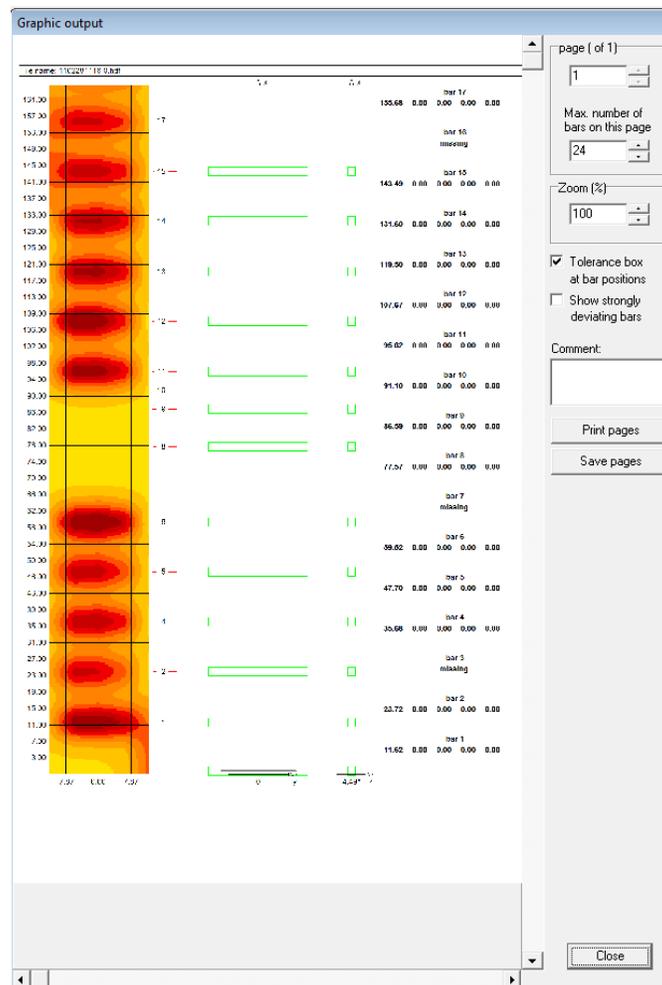
Figure 5

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The dialog box shows a sideways preview of the images to be saved or printed. One check box enables the user to decide whether bars deviating strongly from the desired positions are displayed or not. When positions deviate from the planned positions, or when signals are strongly influenced by close objects like tie bars, exact results cannot be assured. Therefore the display of wrong results can be avoided by this option. On the other hand, showing them can be useful during the analysis because it helps the user to judge the plausibility of the results.

There are green rectangles, the **tolerance boxes**, which give the user a better visual impression of the accuracy of dowel positions. Their height is determined by the tolerance of the horizontal misalignment while their width is computed from the bar length and the tolerance of the side shift. The small *tolerance boxes* are determined by the vertical and the horizontal misalignment tolerances. A bar lying within the tolerance has to be inside the *tolerance box*. It is difficult to judge the misalignment visually because if the bar is situated a bit away from its planned X-position, then it will be the same distance from the *tolerance box* as well. Therefore a check box offers the opportunity to shift the *tolerance boxes* to the bar positions.

By setting the **maximum count of bars** on a page, the bars can be evenly distributed on different sheets. A **comment** can be put into a text field and is displayed in the header of the sheet.

4.   MODIFYING BATCH PROCESSING FILES

4.1 A weighted-score system will be used to conduct a joint-by-joint evaluation of rotational misalignments of the dowel bars. The Joint Score, as defined in this evaluation, is a measure of the combined effects of rotational misaligned dowel bars at a joint. A Joint Score is determined by summing the product of the weights (given in Table 1) and the number of bars in each misalignment category and adding 1. For example, if a joint has four misaligned bars in the 0.6 to 0.8 in. range, the joint score is 9; if a joint has one misaligned bar in the range 0.6 to 0.8 in. and one bar in the 1 to 1.5 in. range, the score is 8. A Joint Score of 10 is the critical level, above which the risk of joint locking is considered high.

Table 1. Weighting Factors Used to Determine Joint Score

Range of Rotational Misalignment	Weight
0.4 in < d < 0.6 in.	0
0.6 in < d < 0.8 in.	2
0.8 in < d < 1 in.	4
1 in < d < 1.5 in.	5

A Joint Score can be evaluated separately or in conjunction with the spreadsheet generated in the batch process – by adding additional columns and formulas that calculate the Joint Score.

An example of a spreadsheet showing the results of the MIT scan, as well as calculating the joint score can be seen in Figure 6.

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Formula bar — M59: `=IF(L59<0.6,0,IF(L59<0.8,2,IF(L59<1,4,IF(L59<1.5,5,"Reject"))))`

#	File name	High-way	Direction	Station No.	Joint	Lane	Bar No.	X-Po-sition	Depth	Depth Devia-tion	Side Shift	Misa-lign-ment	Joint Score	Horiz. Misal.	Vert. Misal.	Minimal Cover
	DN	HW	Dir	SNo	Jo	La	BNo	xs	zs	dz	dy	s		sh	sv	c
	-	-	-	-	-	-	-	inch	inch	inch	inch	inch	Factor	inch	inch	inch
70	0501010118 0.hdf	I 15	North	1474-40	7	Out. sh.	2.00	18.22	7.16	0.66	1.12	1.20	5.00	1.18	0.25	6.28
71	0501010118 0.hdf	I 15	North	1474-40	7	Out. sh.	3.00	30.24	6.90	0.40	0.44	0.18	0.00	0.17	-0.06	6.11
72	0501010118 0.hdf	I 15	North	1474-40	7	Out. sh.	4.00	42.31	6.78	0.29	0.22	0.31	0.00	-0.31	-0.03	6.01
73	0501010118 0.hdf	I 15	North	1474-40	7	Out. sh.	5.00	54.22	6.90	0.41	0.47	0.35	0.00	0.01	0.35	5.97
74	0501010118 0.hdf	I 15	North	1474-40	7	Out. sh.	8.00	90.48	6.58	0.09	0.62	0.14	0.00	0.11		
75	0501010118 0.hdf	I 15	North	1474-40	7	Out. sh.	9.00	102.46	6.44	-0.06	0.62	0.15	0.00	-0.15		
76	0501010118 0.hdf	I 15	North	1474-40	7	Out. sh.	10.00	114.34	6.43	-0.07	0.38	0.52	0.00	0.30		
77	0501010118 0.hdf	I 15	North	1474-40	7	Out. sh.	11.00	126.46	6.21	-0.29	0.80	0.29	0.00	-0.02		
78	0501010118 0.hdf	I 15	North	1474-40	7	Out. sh.	12.00	138.47	6.16	-0.34	1.39	0.66	2.00	0.10		
79	0501010118 0.hdf	I 15	North	1474-40	7	Out. sh.	13.00	150.31	6.19	-0.30	1.19	0.74	2.00	0.07	0.74	5.07
80													10.00			
81	0501010118 1.hdf	I 15	North	1473-85	8	Out. sh.	2.00	18.10	7.03	0.53	-2.77	0.85	4.00	0.78	-0.32	6.11
82	0501010118 1.hdf	I 15	North	1473-85	8	Out. sh.	3.00	30.16	6.68	0.18	-2.74	0.24	0.00	0.18	-0.16	5.84
83	0501010118 1.hdf	I 15	North	1473-85	8	Out. sh.	4.00	42.27	6.76	0.26	-3.03	0.35	0.00	-0.18	-0.30	5.85
84	0501010118 1.hdf	I 15	North	1473-85	8	Out. sh.	5.00	54.05	6.71	0.21	-2.82	0.14	0.00	0.12	-0.06	5.92
85	0501010118 1.hdf	I 15	North	1473-85	8	Out. sh.	8.00	90.29	6.42	-0.08	-2.55	0.37	0.00	0.19	-0.31	5.51
86	0501010118 1.hdf	I 15	North	1473-85	8	Out. sh.	9.00	102.34	6.36	-0.14	-2.53	0.30	0.00	-0.02	-0.30	5.45
87	0501010118 1.hdf	I 15	North	1473-85	8	Out. sh.	10.00	114.21	6.29	-0.21	-2.49	0.47	0.00	-0.16	-0.44	5.31
88	0501010118 1.hdf	I 15	North	1473-85	8	Out. sh.	11.00	126.30	6.18	-0.32	-2.24	0.39	0.00	0.12	-0.37	5.24
89	0501010118 1.hdf	I 15	North	1473-85	8	Out. sh.	12.00	138.32	6.03	-0.46	-1.75	0.28	0.00	0.06	0.28	5.13
90	0501010118 1.hdf	I 15	North	1473-85	8	Out. sh.	13.00	150.08	6.18	-0.32	-1.97	0.28	0.00	0.15	0.24	5.30
91													5.00			
92	0501010119 0.hdf	I 15	North	1474-55	8	Out. sh.	2.00	18.05	7.10	0.60	-1.88	1.48	5.00	0.33	-1.44	5.62
93	0501010119 0.hdf	I 15	North	1474-55	8	Out. sh.	3.00	30.16	6.84	0.35	-0.12	0.13	0.00	0.03	-0.12	6.02
94	0501010119 0.hdf	I 15	North	1474-55	8	Out. sh.	4.00	42.13	7.00	0.50	-0.72	0.78	2.00	-0.41	-0.66	5.91
95	0501010119 0.hdf	I 15	North	1474-55	8	Out. sh.	5.00	54.14	6.79	0.29	-0.29	0.14	0.00	0.08	-0.11	5.98
96	0501010119 0.hdf	I 15	North	1474-55	8	Out. sh.	8.00	90.28	6.48	-0.01	-0.04	0.25	0.00	0.04	-0.25	5.60
97	0501010119 0.hdf	I 15	North	1474-55	8	Out. sh.	9.00	102.29	6.41	-0.08	-0.09	0.29	0.00	-0.07	-0.28	5.51
98	0501010119 0.hdf	I 15	North	1474-55	8	Out. sh.	10.00	114.17	6.41	-0.08	-0.22	0.49	0.00	-0.17	-0.46	5.43
99	0501010119 0.hdf	I 15	North	1474-55	8	Out. sh.	11.00	126.28	6.29	-0.21	-0.12	0.78	2.00	-0.06	-0.78	5.14
100	0501010119 0.hdf	I 15	North	1474-55	8	Out. sh.	12.00	138.25	6.15	-0.35	0.77	0.29	0.00	0.09	0.27	5.25
101	0501010119 0.hdf	I 15	North	1474-55	8	Out. sh.	13.00	150.11	6.16	-0.34	0.74	0.73	2.00	0.09	0.73	5.04
102													12.00			

Joint Score Calculation

Figure 6

5. CORRECTIVE MEASURES

5.1 HORIZONTAL OR VERTICAL MISALIGNMENT

- Saw-Cut the misaligned bars.
- Retrofit dowel bars (Figure 7) to ensure that at least three bowel bars are provided in each wheel path that satisfies the Target Tolerances.

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Figure 7

5.2 LONGITUDINAL (SIDE) SHIFT AND MISSING BARS

- Retrofit dowel bars (Figure 7) to ensure that at least three dowel bars are provided in each wheel path that satisfies the Target Tolerances.

5.3 DEPTH

- Inadequate cover over the bars – If the problem bar can be removed, remove the entire bar and retrofit replacement bars (Figure 7) to ensure that at least three dowel bars are provided in each wheel path that satisfy the Target Tolerances. If the problem bar cannot be removed, perform full-depth repair, in accordance with Section 412.
- Inadequate cover below the bar – retrofit replacement bars (Figure 7) to ensure that at least three dowel bars are provided in each wheel path that satisfies the Target Tolerances.

5.4 In addition to the above written procedures, the contractor may propose full depth removal and replacement of the joint.

6. WHAT TO LOOK FOR WHEN REVIEWING DATA
    See Figure 8, for various scenarios.
    a. Has the joint score been calculated in accordance with the specification?
    b. Are there 2 or more consecutive joints with a Joint Score of greater than 10? If multiple adjacent failing joint scores are due to rotationally misaligned bars, then retrofitting for correction is required to eliminate distress due to locked joints. If an isolated single joint has a failing joint score due to rotationally misaligned bars then joint locking may not be detrimental and retrofitting may not be necessary provided bar depth and embedment are sufficient.
    c. Are there any single bars that meet or exceed the Rejection Tolerance, which would require corrective measures?

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Figure 8

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7.   ADDITIONAL QUESTIONS

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