The Perfect Storm Worksheet – Answer Sheet

The transmitter senses the water pressure (sensor's input), which is determined by the water height in the tank; the transmitter sends a representative signal (transmitter's output) to the plant's control system. The transmitter's *LINEAR* output signal represents water height in the tank, in such a way that a signal of 4 milliamps represents a water level of 0 feet, and a signal of 20 milliamps represents a level of 19.6 feet of water. We used this pressure pump to apply a precise pressure to the sensor at 5 points along its "input range" and we wrote down the output signal values for each step. We need to see if the sensor's output is within 2% tolerance, of the original input versus output signal range it was calibrated to represent.

Below are the data we gathered from the transmitter. Is this within tolerance? Use this worksheet to help us solve this problem.

Input (ft)	0	4.9	9.8	14.7	19.6
Actual Output (mA)	3.96	7.76	11.52	15.52	19.4
Expected Output(mA)	*4*	*8*	*12*	*16*	*20*
Percent Error	*-.25%*	*-1.5%*	*-3%*	*-3%*	*-3.75%*

The **actual output** values are the actual values from the transmitter. We're not sure if they are accurate so we need to find the **expected output** values from a mathematical model. By comparing the expected and actual output values, we can determine if the transmitter is functioning correctly. To create a math model we need to know a little about the tank and the transmitter. The tank can have between 0 to 19.6 feet of water in it. The transmitter ranges from 4 to 20 mA. Thus if there is 0 feet of water in the tank, the transmitter should read 4mA. If there is 19.6 feet of water in the tank the transmitter should read 20mA. This will take a few steps. Are you ready?

Create a linear equation and then fill in the expected outputs.

1. Define your variables in a complete sentence and algebraically.

   Y or Expected Outcome: Milliamps measured by the transmitter when working accurately. The transmitter senses water pressure.

   X or Input: Water level in the tank, which is the water height in feet.

2. Determine the constants of the equation. For linear equations, this is the slope and the y-intercept.
   a: Y-intercept

   Y = a + bX; a = Y(When x=0) –bX(x=0); a=Y(When x=0); a = 4

   b: the slope

   Y = a + bX; Y(when x=19.6) = 4 + b X(X=19.6); 20 = 4 + 19.6b; b = 16/19.6 = .816

3. Create the linear equation.

   Y = a + bX; Y = 4 + .816X

4. Use the input values in the above table and your linear equation to fill in the expected output values in the table. Good job! Compare the actual and expected output values. Are they the same or different? Why?

   They are different because the transmitter is not working accurately; it is producing readings that are not free from error.

5. A percent is a fraction. To find the Percent Error, divide the difference between the actual and the expected output values by the overall range of the transmitter. Fill in the table.

$$\%Error = \frac{Actual - Expected}{Overall\ Range}$$

6. Are these values positive, negative or both? Why?

   They are negative because the transmitter is slightly underestimating the water pressure in the tank. As a result, the transmitter readings obtained represent lower water levels than the actual water levels.

7. Are there units for the percent error? Why or why not?

No, percent of error is expressed in percentages, which are "dimensionless" numbers, numbers that have no units attached. In this case, the percent of error is telling us how accurately the transmitter works regardless of the units in which the measurements are expressed.

Great work! Thank you for the careful analysis. Now let's see if this transmitter is functioning within tolerance. The magic number is 2%. Is the transmitter within 2% tolerance?

No, as the water level in the tank increases the transmitter works less and less precisely. The last three measurements provided by the transmitter have a percent of error higher than 2%.

Essay question

Your boss thanks you for all your hard work and now needs you to write up a report. This report will be read by all new recruits so something like this NEVER HAPPENS AGAIN. Explain in detail exactly what happened:

Paragraph one

- What was the original problem?
- Why did you collect data? Why are you comparing output with the **expected value**?

Paragraph two

- What did you find? What did the data tell you?
- Was the transmitter functioning within tolerance?
- What do you suggest needs to be done?

*The original problem was to determine whether a transmitter used to measure the water pressure in a tank was working **accurately enough** (i.e., within 2% tolerance – the error in measurement that is acceptable in this case-). I collected data on the actual values provided by the transmitter (i.e., transmitter readings) to compare them with the expected values/readings that a transmitter functioning accurately would have yielded. By doing this, I could compute the percent errors in measurement, and thus determine whether the transmitter was functioning **accurately enough** (i.e., 2% tolerance). To compute expected values, I created a linear equation. I knew that if there was 0 feet of water in the tank, the transmitter should have read 4mA and that if there was 19.6 feet of water in the tank the transmitter should have read 20mA. I collected both expected and actual values along 5 points in* the "input range", being the input the water level in the tank.

I found that the transmitter was not functioning within 2% tolerance. Consequently, estimating the water level in the tank could not be done with enough confidence. I suggest having an Instrument Technician calibrate the transmitter in order to obtain accurate transmitter readings so that going forward we can fairly estimate the water level in the tank.

Video 2

Scene 1 - Grant and Boris

- Boris, “Thanks for the help! Did you find that the transmitter was out of tolerance?”
- Grant, “Now we know what to fix. If you’d like more information about the work we do, check out my story on Baywork”
- Weblink appears