EPO No. 16

Appendix (Supplement 3)

Determining Scale Error When Applying the Alternative Substitution Test Method

This supplement is intended to further clarify how scale error is determined from hypothetical results, made up to imitate those that might be recorded by an official who applied the various steps of the alternative substitution test method to perform an increasing-load test on a scale with digital indication. The results of having applied each step of the test are shown with sufficient notation to make clear how the substitution test loads were created and scale error determined from using error weights. Shading is used to differentiate between values associated with the most current step from those of previous steps.

Types of Error:

When using the alternative substitution test method, there are two types of errors you will need to consider:

1) The error associated with each step of the increasing-load test in which test weight is applied from a proper starting reference. These are referred to herein as "step errors." You will see these errors recorded in the column of the example tables titled: "Error (E_n)"
2) The error associated with the cumulative results of one or more steps in which test weight is applied during of the increasing-load test. These errors are referred to herein as "cumulative errors." Cumulative errors are determined by summing the results of consecutive increasing-load steps . You will see these errors recorded in the column of the example tables titled: "Error ($\sum E_n$)"

Tolerance Application:

Tolerances apply to both types of error as follows:

1) Step Errors: Tolerances apply to the error corresponding to the test weight portion of each test load applied during the increasing-load test, including test loads comprised of substituted material and test weight.
2) Cumulative Errors: Tolerances apply to the error corresponding to the cumulative results of two or more consecutive increasing-load steps in which test weight is applied from a proper starting reference established at no load and each substitution load therefrom.

Establish a proper reference at no load (high-level step 1)

Test Description	Test Weight	Substituted Bulk	Starting Reference	Ending Reference	Scale Indication	Error (E_n)	Error ($\sum E_n$)	

	(L)	Material	(R_s)	(R_e)	(I_x)			
Zero load	0	0		6	10/20			

Apply the test weight load, establish proper reference, and determine the total amount of scale error (high level steps 2 and 3)

Test Description	Test Weight (L)	Substituted Bulk Material	Starting Reference (R_s)	Ending Reference (R_e)	Scale Indication (I_x)	Error (E_n)	Error ($\sum E_n$)	
Zero load	0	0		6	10/20			
Increase	3 000		6	9	3 010/20	-3	-3	Step 1

The following formula is used to determine the amount of error (i.e., step error) in the scale at the first applied test weight load:

$$E_n = I_e - I_s - L + R_s - R_e$$

Where:

"E_n" *(Error)* represents the amount of error in the scale relative to the applied test weight portion of the total applied test load;

"I_e" *(Indication ending)* represents the scale indication after the test weight has been applied and proper reference established;

"I_s" *(Indication start)* represents the scale indication before the test weight was applied;

"L" *(Load)* represents the value of the applied test weight excluding any substituted load;

"R_s" *(Reference start)* represents the value of the error weights on the load-receiving element that established proper reference prior to the test weight being applied; and

"R_e" *(Reference ending)* represents the value of the error weights on the load-receiving element that established proper reference after the test weight had been applied.

Thus, from the values recorded in the Table above:

"I_e" is equal to 3 015
"I_s" is equal to 15
"L" is equal to 3 000
"R_s" is equal to 6
"R_e" is equal to 9

To determine the amount of error in the scale, insert the appropriate corresponding values obtained during testing into the formula and solve the equation as follows:

$$E_n = I_e - I_s - L + R_s - R_e$$

Actual test result values (from Table above) inserted into the formula:

$$E_n = 3\,015 - 15 - 3\,000 + 6 - 9$$

Completed formula calculation : Error = - 3

Evaluating the Results:

Since only test weights have been applied thus far during testing, the cumulative results are the same as the error for Step 1.

Verify return to no-load reference (high-level step 4)

Test Description	Test Weight (L)	Substituted Bulk Material	Starting Reference (R_s)	Ending Reference (R_e)	Scale Indication (I_x)	Error (E_n)	Error ($\sum E_n$)	
Zero load	0	0		6	10/20			
Increase	3 000		6	9	3 010/20	-3	-3	Step 1
Zero Return	0	0	6	7	10/20	-1*		

* Note from the shaded area that error weight in the amount of 6 pounds was initially balanced in to create proper reference at zero load. However, after the test weights were applied and then removed to verify zero return, 7 pounds of error weight was needed to duplicate proper reference, thus resulting in a - 1 pound balance change.

Create the first substitution test load and establish proper reference (high-level step 5)

Test Description	Test Weight (L)	Substituted Bulk Material	Starting Reference (R_s)	Ending Reference (R_e)	Scale Indication (I_x)	Error (E_n)	Error ($\sum E_n$)	
Zero load	0	0		6	10/20			
Increase	3 000		6	9	3 010/20	-3	-3	Step 1
Zero Return	0	0	6	7	10/20	-1		
1st Sub.		2 980		1	2 980/90			

Apply test weight to first substitution test load, establish proper reference, and determine the total amount of scale error (high-level steps 6 and 7)

Test Description	Test Weight (L)	Substituted Bulk Material	Starting Reference (R_s)	Ending Reference (R_e)	Scale Indication (I_x)	Error (E_n)	Error ($\sum E_n$)	
Zero load	0	0		6	10/20			
Increase	3 000		6	9	3 010/20	-3	-3	Step 1
Zero Return	0	0	6	7	10/20	-1		
1st Sub.		2 980		1	2 980/90			
Increase	3 000	2 985	1	6	5 980/90	-5	-8	Step 2

To determine the amount of error in the scale corresponding to the test weight portion of the test load (i.e., step error), insert the appropriate values obtained during testing into the formula and solve the equation as follows:

$$E_n = I_e - I_s - L + R_s - R_e$$

Actual test result values from the table above illustrating the results of high-level steps 6 and 7 inserted into the formula:

$$E_n = 5\ 985 - 2\ 985 - 3\ 000 + 1 - 6$$

Completed formula calculation : Error = - 5

Evaluating the Results:

Tolerances apply to:

1) the error corresponding to the test weight portion (i.e., 3 000 pounds) of the applied load for this particular increasing-load step; and
2) the error corresponding to the cumulative results of having applied the test weight twice; the first of which, resulted in a - 3 pound error, and the second of which, resulted in a - 5 pound error. Thus, the cumulative error corresponding to the first two increasing-load steps is - 8 pounds.

In order for the example scale to meet applicable tolerances:

1) the result (error) associated with the addition of the test weight in each step of the increasing-load test (identified in the table as "Increase") must be within applicable tolerance in relation to the test weight amount applied in each of those steps; and
2) the cumulative results (error) of the two increasing-load steps completed thus far, must also be within tolerance. That is, the sum of the error recorded in each of the increasing-load steps completed thus far in relation to the sum of the test weight applied in each of those same steps must be within tolerance. In the two increasing-load steps completed thus far, the cumulative error is - 8 pounds and the sum of the test weight applied is 6 000 pounds.

Create the second substitution test load and establish proper reference (high-level tep 8)

Test Description	Test Weight (L)	Substituted Bulk Material	Starting Reference (R_s)	Ending Reference (R_e)	Scale Indication (I_x)	Error (E_n)	Error ($\sum E_n$)	
Zero load	0	0		6	10/20			
Increase	3 000		6	9	3 010/20	-3	-3	Step 1
Zero Return	0	0	6	7	10/20	-1		
1st Sub.		2 980		1	2 980/90			
Increase	3 000	2 985	1	6	5 980/90	-5	-8	Step 2
2nd Sub.		5 950		9	5 950/60			

Apply test weight to the second substitution test load, establish proper reference, and determine the total amount of scale error (high-level steps 9 and 10)

Test Description	Test Weight (L)	Substituted Bulk Material	Starting Reference (R_s)	Ending Reference (R_e)	Scale Indication (I_x)	Error (E_n)	Error ($\sum E_n$)	
Zero load	0	0		6	10/20			
Increase	3 000		6	9	3 010/20	-3	-3	Step 1
Zero Return	0	0	6	7	10/20	-1		
1st Sub.		2 980		1	2 980/90			
Increase	3 000	2 985	1	6	5 980/90	-5	-8	Step 2
2nd Sub.		5 950		9	5 950/60			
Increase	3 000	5 955	9	8	8 950/60	+1	-7	Step 3

To determine the amount of error in the scale corresponding to the test weight portion of the test load (i.e., step error), insert the appropriate corresponding values obtained during testing into the formula and solve the equation as follows:

$$E_n = I_e - I_s - L + R_s - R_e$$

Actual test result values from the table above illustrating the results of high-level steps 9 and 10 inserted into the formula:

$$E_n = 8\,955 - 5\,955 - 3\,000 + 9 - 8$$

Completed formula calculation : Error = + 1

Evaluating the Results:

Tolerances apply to:

1) the error corresponding to the test weight portion (i.e., 3 000 pounds) of the total applied load for this particular step; and
2) the error corresponding to the cumulative results of having applied the test weight three times (i.e., once in each of the three consecutive increasing-load steps). The cumulative error corresponding to the three increasing-load steps completed thus far is - 7 pounds.

In order for the example scale to meet applicable tolerances:

1) the result (error) associated with the addition of the test weight in each step of the increasing-load test (identified in the table as “Increase”) must be within

applicable tolerance in relation to the test weight amount applied in each of those steps; and

2) the cumulative results (errors) of all increasing-load steps completed thus far, must also be within tolerance. That is, the sum of the error recorded in each of the increasing-load steps completed thus far in relation to the sum of the test weight applied in each of those same steps must be within tolerance. In the three increasing-load steps completed thus far, the cumulative error is - 7 pounds and the sum of the test weight applied in each of those same steps is 9 000 pounds.

Create the third substitution test load and establish proper reference (high-level step 11)

Test Description	Test Weight (L)	Substituted Bulk Material	Starting Reference (R_s)	Ending Reference (R_e)	Scale Indication (I_x)	Error (E_n)	Error ($\sum E_n$)	
Zero load	0	0		6	10/20			
Increase	3 000		6	9	3 010/20	-3	-3	Step 1
Zero Return	0	0	6	7	10/20	-1		
1st Sub.		2 980		1	2 980/90			
Increase	3 000	2 985	1	6	5 980/90	-5	-8	Step 2
2nd Sub.		5 950		9	5 950/60			
Increase	3 000	5 955	9	8	8 950/60	+1	-7	Step 3
3rd Sub.		8 950		3	8 950/60			

Apply the test weight to the third substitution load, establish proper reference, and determine the total amount of scale error (high-level steps 12 and 13)

Test Description	Test Weight (L)	Substituted Bulk Material	Starting Reference (R_s)	Ending Reference (R_e)	Scale Indication (I_x)	Error (E_n)	Error ($\sum E_n$)	
Zero load	0	0		6	10/20			
Increase	3 000		6	9	3 010/20	-3	-3	Step 1
Zero Return	0	0	6	7	10/20	-1		
1st Sub.		2 980		1	2 980/90			
Increase	3 000	2 985	1	6	5 980/90	-5	-8	Step 2
2nd Sub.		5 950		9	5 950/60			
Increase	3 000	5 955	9	8	8 950/60	+1	-7	Step 3
3rd Sub.		8 950		3	8 950/60			
Increase	3 000	8 955	3	8	11 950/60	-5	-12	Step 4

To determine the amount of error in the scale corresponding to the test weight portion of the test load (i.e., step error), insert the appropriate corresponding values obtained during testing into the formula and solve the equation as follows:

$$E_n = I_e - I_s - L + R_s - R_e$$

Actual test result values from the table above illustrating the results of high-level steps 12 and 13 inserted into the formula:

$$E_n = 11\,955 - 8\,955 - 3\,000 + 3 - 8$$

Completed formula calculation : Error = - 5

Evaluating the Results:

Tolerances apply to:

1) the error corresponding to the test weight portion (i.e., 3 000 pounds) of the total applied load for this particular step; and
2) the error corresponding to the cumulative results of having applied the test weight four times (i.e., once in each of the four consecutive increasing-load steps). The cumulative error corresponding to the four increasing-load steps completed thus far is - 12 pounds.

In order for the example scale to meet applicable tolerances:

1) the result (error) of each individual step of the increasing-load test (identified in the table as "Increase") must be within applicable tolerance in relation to the test weight amount applied in that particular step; and
2) the cumulative results (errors) of all increasing-load steps completed thus far, must also be within tolerance. That is, the sum of the error recorded in each individual increasing-load step completed thus far, in relation to the sum of the test weight applied in each of those same steps. In the four increasing-load steps completed thus far, the cumulative error of - 12 pounds and the sum of the test weight applied in each of those same steps is 12 000 pounds.

Recording the Results of Additional Testing (If Necessary)

Note: If maximum test load has not been achieved after the test weights are applied to the third substitution test load, it will be necessary to develop additional substitution test loads and apply the test weights to those test loads as many additional times as needed to complete the test. These additional tests are to be performed in the same manner as those before them and the results recorded the same way.