

A.I. Tolerancing

Traditional tolerancing approaches are based solely on numeric descriptions of the color. You typically begin by identifying a single number, DE, which can be used universally to define the acceptability of the color match. When additional parameters, such as DL^* , Da^* , Db^* , DC^* and DH, are added to the tolerance, you create an acceptability ellipsoid around the standard in color space. Batches are evaluated based on whether they fall relative to the acceptability ellipsoid.

We have learned through working with instrumental tolerancing systems that, although the numbers are consistent, they do not always tell the complete story about the acceptability of a color match. Regardless of the color space model and color difference formula chosen, you have probably generated instrumental color evaluations that did not agree with your visual evaluation of the samples. Often when there is a conflict between the visual and instrumental evaluation of the sample, you either physically adjust a batch that doesn't need adjustment in order to satisfy the numerical tolerances, or 'pass' a batch that has 'failed' instrumentally. In either case, the approval process is delayed.

The Artificial Intelligence Pass/Fail (A.I. P/F) feature was developed to address these limitations with instrumental tolerancing. Unlike traditional methods that work exclusively with instrumental evaluations, A.I. P/F incorporates your visual assessments of the samples into the creation of the tolerances. This results in instrumental evaluations that more closely correlate with your visual evaluation of the samples.

Unlike traditional instrumental tolerances, you will notice that A.I. P/F tolerances are not always symmetrical around the standard. This is because A.I. tolerances are based on visual evaluations. In many cases, we do not visually 'tolerate' symmetrical differences. For example, we may be able to accept a sample that is lighter than the standard, but not one that is darker. A.I. P/F also indicates its 'certainty' regarding each individual evaluation. This is an indication of the confidence it has in the evaluation. Some batches may fall in a region of the ellipsoid where the program does not have enough information to make a definite judgment. It will offer a pass or fail evaluation based on the available data, but it will also indicate that you should check the sample visually.

Finally, the A.I. P/F tolerancing option is designed to allow the system to continually update the tolerances, based on batches made after the initial tolerances have been developed. The program can continue to refine the A.I. tolerances based on the latest batch data.

A.I. Tolerancing Method

A.I. P/F uses the CIELab coordinates (DC^* , DH^* , and DL^*) of the standard and the batches to determine an ellipsoidal acceptability volume in CIELab color space. This ellipsoid can be non-symmetrical around the standard or even skewed away from the standard depending on the data used in training.

A.I. P/F Value or DE

After the DC^* , DH^* , and DL^* tolerances are determined through A.I. P/F training, the program performs the following calculation to make a pass/fail determination:

In the above equation, the DC , DH , and DL represent the CIELAB DC^* , DH^* , and DL^* of a measured batch. The DC_{tol} , DH_{tol} , and the DL_{tol} represent the A.I. pass/fail tolerances for the standard.

If the A.I. P/F value is greater than 1, it indicates the batch falls outside of the ellipsoidal acceptability volume and the batch will fail. If the A.I. P/F value is less than 1, it indicates that the batch falls inside the ellipsoidal acceptability volume and the batch will pass. If the A.I. P/F value equals 1, it indicates that the batch falls on the surface of the ellipsoidal acceptability volume. The number "1" will always determine pass or fail for the A.I. P/F value even though the shape of the ellipsoid may be very different for different standards.

A.I. P/F Procedure

Below is the procedure for implementing the A.I. P/F feature:

1. Visually evaluate all of your batches.
2. Measure or recall the standard.
3. Measure all of the batches.
4. Choose **Std, Screen Form, A.I. P/F Training**.
5. Mark samples.
6. 'Train' the system.
7. Evaluate the data.
8. Store the A.I. tolerances.
9. Run A.I. P/F on new batches.

Training the Standard

Physical samples representing batches must be available for someone to make visual pass or fail judgments. You will measure the batches and use the 'training' option (*Forms Menu, Screen Forms, AI P/F Training Form*) to produce ellipsoidal A.I. P/F tolerances.

Measuring Samples

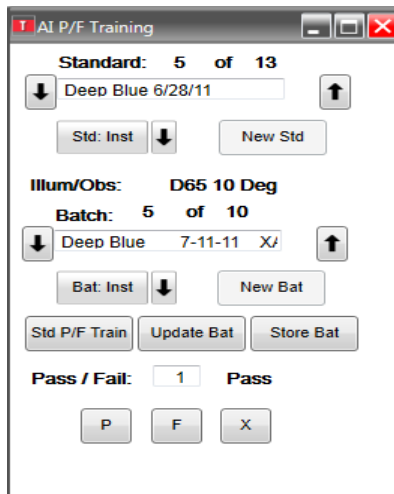
- A On the desktop, measure or recall the standard.
- B Measure each batch than has been evaluated visually. It is important to include batches that you have failed visually in this group of samples.

Marking Samples

Next, the samples are marked as having either passed or failed. This is done using the Visual Tolerance Training form.

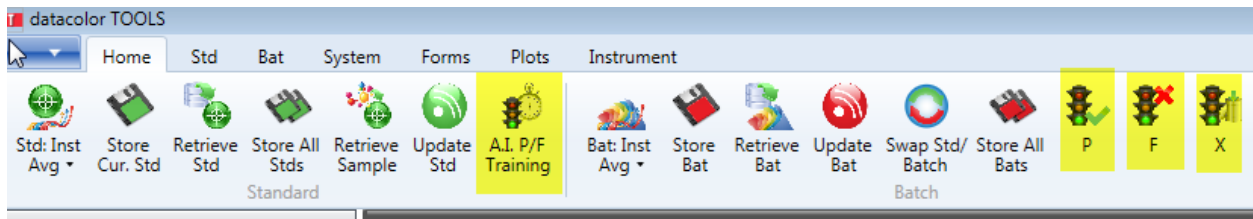
To display this form, do one of the following:

1. Select the form from the screen form list (Forms, Screen, AI P/F Training Form)



The screenshot shows the 'AI P/F Training' window. It has a title bar with a red close button. The main area contains several controls: 'Standard: 5 of 13' with a dropdown showing 'Deep Blue 6/28/11' and 'Std: Inst' buttons; 'Illum/Obs: D65 10 Deg'; 'Batch: 5 of 10' with a dropdown showing 'Deep Blue 7-11-11 X/' and 'Bat: Inst' buttons; 'Std P/F Train', 'Update Bat', and 'Store Bat' buttons; and a 'Pass / Fail: 1 Pass' section with 'P', 'F', and 'X' buttons.

Another better option may be to add the pass, fail, exclude, and A.I. P/F training buttons to the ribbon bar (Shown below). The when searching for the button name they are 'Batch:P', 'Batch:F', 'Batch:X', and 'Standard:A.I P/F Training



2. Click the **P/F Training** button located on the form (or the A.I. P/F training button). The form below displays. In this example, 50 batches are measured against the standard 'DJV01 Blue reference'. The current batch, 'DJO50 Blue 50' is set as 'Exclude', indicating

'Exclude' until they are assigned a pass or fail judgment.

- A. To give the current batch a Pass judgment, click the **Accept Batch** button
- B. To give the current batch a Fail judgment, click on **Reject Batch** button.
- C. To exclude the current batch from the training data, click on the **Exclude Batch** button

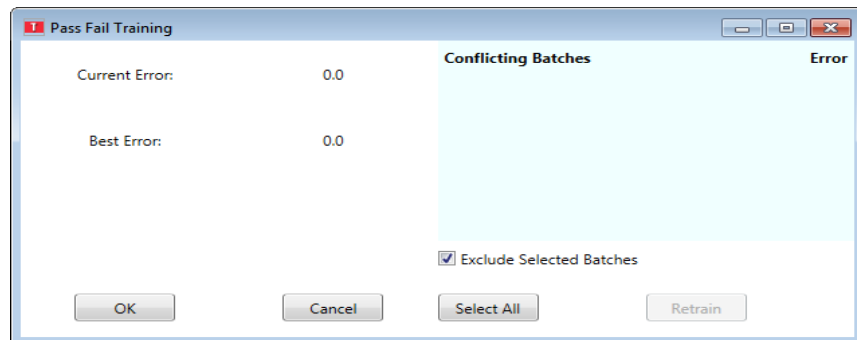
3. Move to the next batch and mark as 'accept' or 'reject' based on your visual evaluation. The program attempts to include the samples that you indicated as a 'pass' into an ellipsoidal shape and to exclude those samples that you indicated as 'fail.'

Starting the A.I. Training

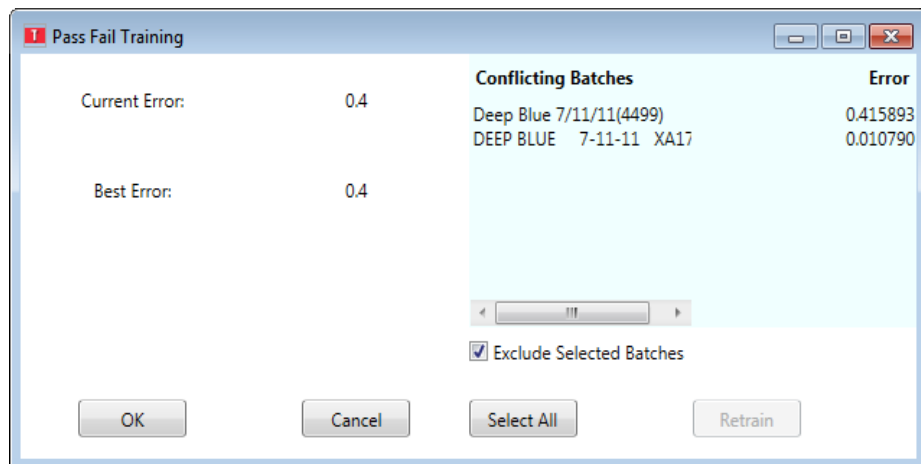
Once you have marked all of the batches, you can begin the A.I. training for the standard. Click on the button 'Std P/F Train' (or the button on the ribbon bar A.I. P/F training)

Std P/F Train

When the training is complete, the Pass/Fail Training dialog box displays:



Errors and Conflicts



Statistical errors and conflicting batches are generated during a P/F training session:

- **Errors.** Errors reflect the presence of conflicting batches. An error of zero indicates that there weren't any conflicting batches.
- **Conflicts.** A conflict can occur if you pass a sample that falls in the same area of color space as one that you failed. In this case, the software cannot exclude the failing sample while including the passing sample. This can occur because of a mistake in input or it may be a visual judgment error.

In this example, there are 2 batches in conflict. The error number displayed for each batch indicates the degree of error. The magnitude of the error indicates the degree of conflict associated with the batch. A higher number indicates that the batch is a greater problem.

Eliminating Conflicts. There are 2 ways to handle conflicting batches.

- The recommended approach is to re-evaluate the visual pass/fail judgment made regarding the conflicting batch. Start with the batches having the highest error. If you decide that the visual evaluation is not correct, you change the judgment and 'retrain' the standard. In many cases, if you change the evaluation of the samples with the greatest error first, the other conflicts may be resolved.
- The fastest way to eliminate the conflict is to 'exclude' the conflicting batches from the training. To exclude a single batch, click on the batch name to highlight it.

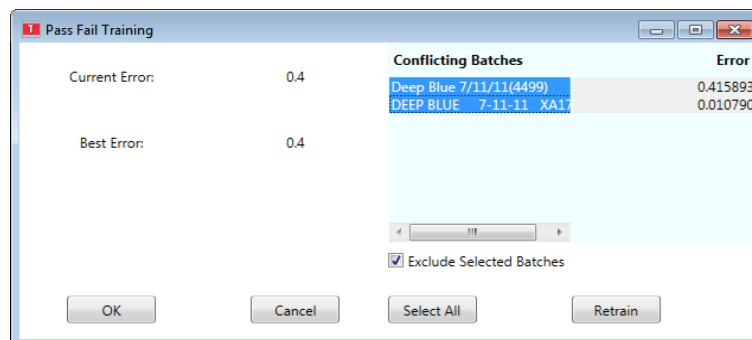
To Exclude a group of batches:

- Hold down the **CTRL** key click on the batches.

To Exclude all conflicting batches:

1. Click the **Select All** button.
2. After excluding the batches. Click on the **Retrain** button to start the training again. The conflicting batches will be excluded.

A.I. P/F Tolerance Plots



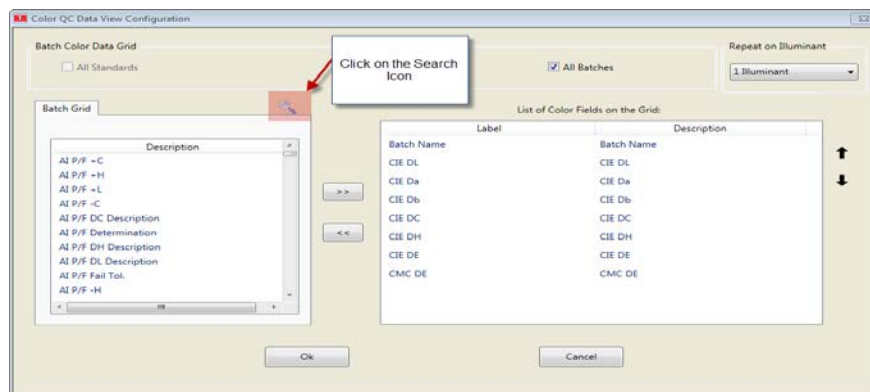
Adding AI fields to a template

1. If you right click within the batch section of the data grid, as is shown below.

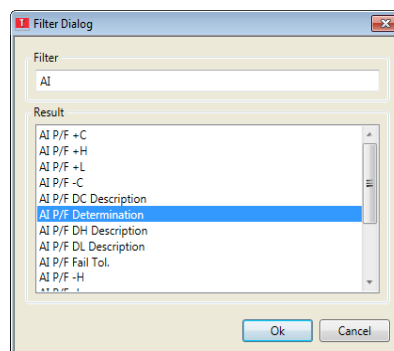
DC QC 3 View Panel Screen Template								
	Std. CIE L	Std. CIE a	Std. CIE b	Std. CIE c	Std. CIE h			
	28.45	8.79	-19.69	21.56	294.05			
	Batch Name	CIE DL	CIE Da	CIE Db	CIE DC	CIE DH	CIE DE	CMC DE
	SN1071 Deep Blue	0.12	-0.11	-0.09	0.04	-0.14	0.18	
	Deep Blue 6/28/11(45	-0.09	0.09	-0.15	0.18	0.02	0.20	
	Deep Blue 6/28/11(46	0.10	-0.09	0.24	-0.26	0.01	0.28	
	Deep Blue 7/11/11(44	0.04	-0.09	0.15	-0.17	-0.02	0.18	
	Deep Blue 7-11-1	-0.14	-0.04	0.25	-0.24	0.07	0.29	
	DEEP BLUE 7-11-11	-0.07	-0.07	0.33	-0.33	0.07	0.35	
	Deep Blue NP 7-11-	-0.02	-0.07	0.32	-0.32	0.07	0.33	
	DEEP BLUE NT 7-11-	0.03	-0.16	0.47	-0.50	0.04	0.50	
	VF Deep Blue Net Incl	-0.13	-0.10	0.36	-0.37	0.06	0.39	

Grid Configuration
Current Batch
Reset Grid
Print
Export
Export all
Switch
Save as template

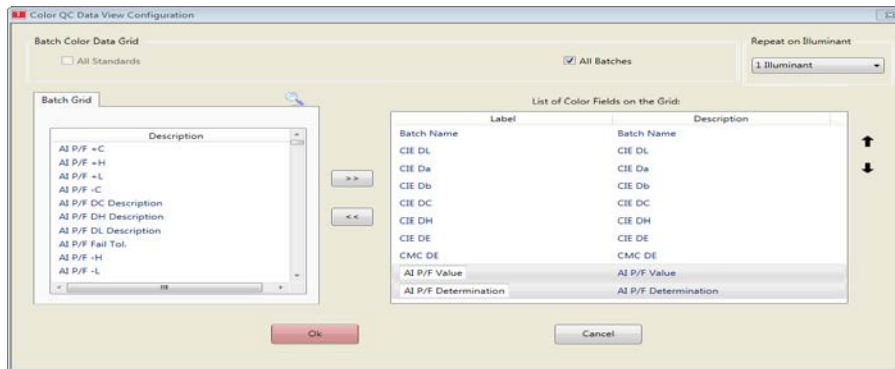
2. When the Configuration page appears click on the search button.



3. The search filter dialog box will appear. You can type in 'AI' to view any component of AI you wish to appear on the template. In this example we will choose 'AI P/F Determination'. We will also choose 'AI P/F DE'



- These components will be added to the template list. And then when you click 'ok', they will be added to the template.



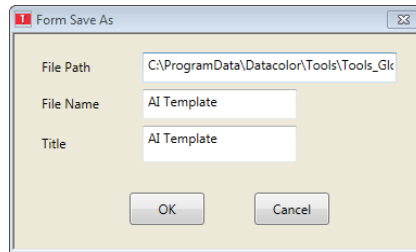
- New AI components added to template.

DC QC 3 View Panel Screen Template											
Std. CIE L		Std. CIE a		Std. CIE b		Std. CIE C		Std. CIE h			
28.45		8.79		-19.69		21.56		294.05			
Batch Name	CIE DL	CIE Da	CIE Db	CIE DC	CIE DH	CIE DE	CMC DE	AI P/F Value	AI P/F Determinati		
SN1071 Deep Blue	0.12	-0.11	-0.09	0.04	-0.14	0.18		1.73	Fail		
Deep Blue 6/28/11(45	-0.09	0.09	-0.15	0.18	0.02	0.20		1.73	Fail		
Deep Blue 6/28/11(46	0.10	-0.09	0.24	-0.26	0.01	0.28		1.73	Fail		
Deep Blue 7/11/11(44	0.04	-0.09	0.15	-0.17	-0.02	0.18		1.73	Fail		
Deep Blue 7-11-1	-0.14	-0.04	0.25	-0.24	0.07	0.29		1.73	Fail		
DEEP BLUE 7-11-11	-0.07	-0.07	0.33	-0.33	0.07	0.35		1.73	Fail		
Deep Blue NP 7-11-	-0.02	-0.07	0.32	-0.32	0.07	0.33		1.73	Fail		
DEEP BLUE NT 7-11-	0.03	-0.16	0.47	-0.50	0.04	0.50		1.73	Fail		
VF Deep Blue Net Incl	-0.13	-0.10	0.36	-0.37	0.06	0.39		1.73	Fail		

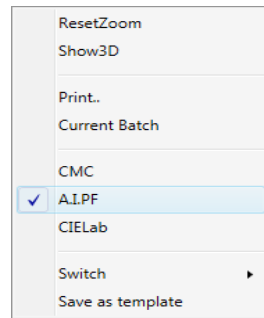
- To save this template right click on the Template and choose 'Save as Template'

DC QC 3 View Panel Screen Template											
Std. CIE L		Std. CIE a		Std. CIE b		Std. CIE C		Std. CIE h			
28.45		8.79		-19.69		21.56		294.05			
Batch Name	CIE DL	CIE Da	CIE Db	CIE DC	CIE DH	CIE DE	CMC DE	AI P/F Value	AI P/F Determinati		
SN1071 Deep Blue	0.12	-0.11	-0.09	0.04				1.73	Fail		
Deep Blue 7/11/11(44	0.04	-0.09	0.15	-0.17				1.73	Fail		
Deep Blue 6/28/11(46	0.10	-0.09	0.24	-0.26				1.73	Fail		
Deep Blue 6/28/11(45	-0.09	0.09	-0.15	0.18				1.73	Fail		
DEEP BLUE NT 7-11-	0.03	-0.16	0.47	-0.50				1.73	Fail		
VF Deep Blue Net Incl	-0.13	-0.10	0.36	-0.37				1.73	Fail		
VF Deep Blue No Net	-0.15	-0.07	0.31	-0.31				1.73	Fail		
Deep Blue 7-11-1	-0.14	-0.04	0.25	-0.24				1.73	Fail		
DEEP BLUE 7-11-11	-0.07	-0.07	0.33	-0.33	0.07	0.35		1.73	Fail		

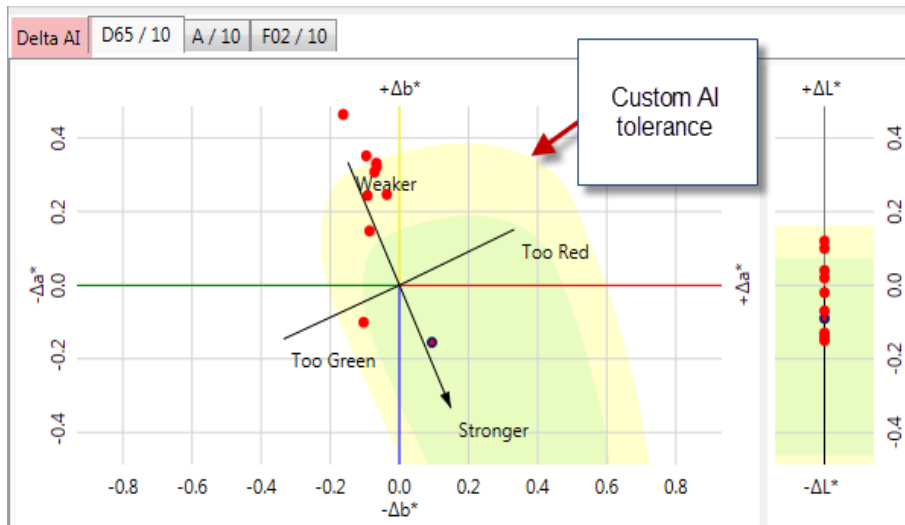
- Fill in the name and the Title and you will permanently save your new template.



8. To view the AI Tolerance on the plot, right click on the plot and choose 'AI PF' if not already chosen to view that plot



9. The AI plot will be shown as below.



10. **Very Important to note** that when we perform an AI pass/fail training on a standard it will create a Standard Tolerance for that standard. This will override the System Tolerance. The Standard tolerance will not include a CMC tolerance with it. Therefore CMC DE will not be display as is shown on our template below. We must add it

AI Template

	Std. CIE L	Std. CIE a	Std. CIE b	Std. CIE C	Std. CIE h
	28.45	8.79	-19.69	21.56	294.05

No CMC DE value displayed because this tolerance is not included in the Standard Tolerance

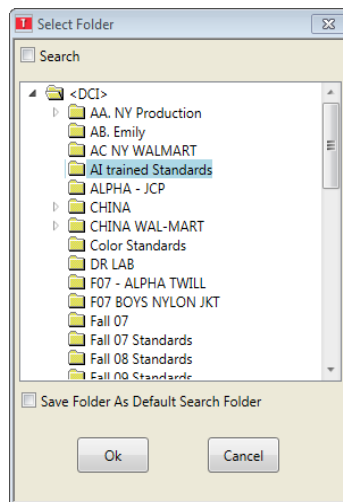
	Batch Name	CIE DL	CIE Da	CIE Db	CIE DC	CIE DH	CIE DE	CMC DE	AI P/F Value	AI P/F Determinati
	SN1071 Deep Blue	0.12	-0.11	-0.09	0.04	-0.14	0.18		1.73	Fail
	Deep Blue 6/28/11(45	-0.09	0.09	-0.15	0.18	0.02	0.20		1.73	Fail
	Deep Blue 6/28/11(46	0.10	-0.09	0.24	-0.26	0.01	0.28		1.73	Fail
	Deep Blue 7/11/11(44	0.04	-0.09	0.15	-0.17	-0.02	0.18		1.73	Fail
	Deep Blue 7-11-1	-0.14	-0.04	0.25	-0.24	0.07	0.29		1.73	Fail
	DEEP BLUE 7-11-11	-0.07	-0.07	0.33	-0.33	0.07	0.35		1.73	Fail
	Deep Blue NP 7-11-	-0.02	-0.07	0.32	-0.32	0.07	0.33		1.73	Fail
	DEEP BLUE NT 7-11-	0.03	-0.16	0.47	-0.50	0.04	0.50		1.73	Fail
	VF Deep Blue Net Incl	-0.13	-0.10	0.36	-0.37	0.06	0.39		1.73	Fail

No CMC DE value displayed because this tolerance is not included in the Standard Tolerance

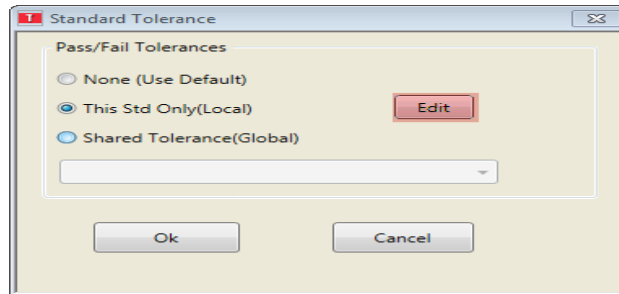
- To add or edit a system tolerance. Make sure you have the proper standard highlighted and choose the 'Std' tab at the top of the Tools program. On this tab we will choose 'Edit Tolerance'



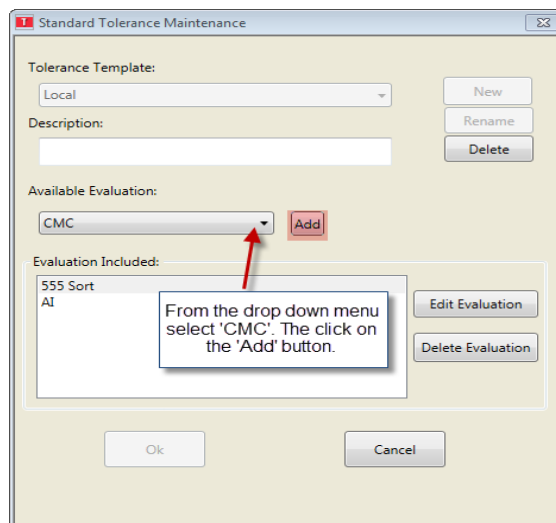
- The system will prompt us to store our standard with the tolerance in a folder. In my example I have chosen the folder 'AI Trained Standards'



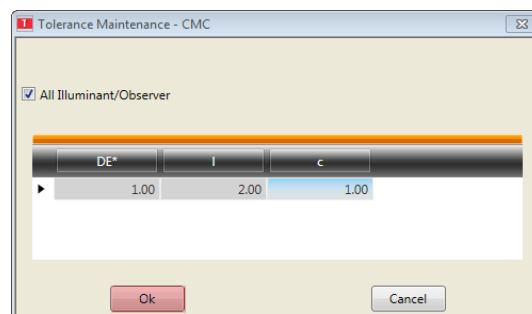
- To add the CMC values you will need to add the CMC Tolerance. Highlight "This Standard Only(Local)" then click on the edit button



14. The Standard Tolerance Maintenance screen will be displayed. From the drop down below select 'CMC'. Then click the button 'Add'



15. The CMC tolerance maintenance screen will be displayed. Fill in you tolerance. In my example DE is 1.0 and l:c ratio is 2:1 respectively. Then click 'ok', then 'ok' again to save that CMC tolerance with the standard.



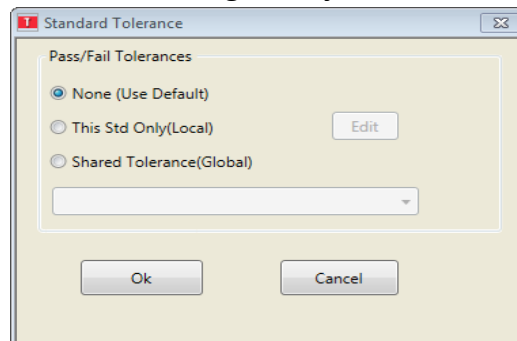
16. Once that standard tolerance is re-saved with the standard you once again will be displaying CMC DE.

AI Template										
	Std. CIE L	Std. CIE a	Std. CIE b	Std. CIE C	Std. CIE h					
	28.45	8.79	-19.69	21.56	294.05					

Batch Name	CIE DL	CIE Da	CIE Db	CIE DC	CIE DH	CIE DE	CMC DE	AI P/F Value	AI P/F Determinati
SN1071 Deep Blue	0.12	-0.11	-0.09	0.04	-0.14	0.18	0.15	1.73	Fail
Deep Blue 6/28/11(45	-0.09	0.09	-0.15	0.18	0.02	0.20	0.12	1.73	Fail
Deep Blue 6/28/11(46	0.10	-0.09	0.24	-0.26	0.01	0.28	0.17	1.73	Fail
Deep Blue 7/11/11(44	0.04	-0.09	0.15	-0.17	-0.02	0.18	0.11	1.73	Fail
Deep Blue 7-11-1	-0.14	-0.04	0.25	-0.24	0.07	0.29	0.18	1.73	Fail
DEEP BLUE 7-11-11	-0.07	-0.07	0.33	-0.33	0.07	0.35	0.21	1.73	Fail
Deep Blue NP 7-11-	-0.02	-0.07	0.32	-0.32	0.07	0.33	0.20	1.73	Fail
DEEP BLUE NT 7-11-:	0.03	-0.16	0.47	-0.50	0.04	0.50	0.29	1.73	Fail
VF Deep Blue Net Incl	-0.13	-0.10	0.36	-0.37	0.06	0.39	0.24	1.73	Fail

CMC DE now included in Standard tolerance so values are displayed for CMC DE

17. It is VERY IMPORTANT to know that if you want to switch back to the system tolerance you will do steps 11 and 12 above for editing a standard tolerance and choose 'Use System Tolerance' instead of 'This Std Only(Local)'. Resave the standard and this will change the tolerance back to using the 'System' or 'Default' Tolerance



Uncertainty

The "Uncertainty" range defines the area where the pass/fail judgment is uncertain because of a lack of data in that area. In these areas, the program will make a pass or fail decision but the word "Check" will be added after a pass or fail decision. This indicates that the sample should be re-evaluated visually. The standard should then be retrained substituting the new visual evaluation. The range of uncertainty should decrease.

The numeric value of the uncertainty relates to the A.I. P/F value of 1. A value of 1 indicates that the batch is on the surface of the acceptability ellipsoid. The uncertainty in the previous example is 0.9747 - 1.0192. Samples with an A.I. P/F value of less than .9747 are certain passes. From .9747 to 1.0, the samples will be passed but with a "Check" added. Samples with a P/F value greater than 1.0192 are certain fails. From 1.0 to 1.0192, the samples will be failed but with a "Check" added. The uncertainty value in the above example is very good. This indicates uncertainty near the surface of the ellipsoid.

If you trained a group of samples and marked them all pass, you would generate a very large uncertainty value. The ellipsoid would be defined solely on 'passing' samples. Since there are no samples that fail, the uncertainty would be great outside the ellipsoid.

To reduce the uncertainty regarding the tolerances, you should visually re- evaluate all of the samples that were marked 'check'. You should mark them again, based on your new evaluation, and 'retrain' the standard. The acceptability ellipsoid will be redefined, based on changes you've made to the visual evaluation of the batches, and there should be less 'uncertainty'.

Storing A.I. P/F Tolerances

After you are satisfied with the training session, you can store the new A.I. P/F tolerances with the standard by clicking the **OK** button.

Performing A.I P/F Evaluation

1. Retrieve standard to be used in evaluation.
2. Measure or Retrieve current batches to be evaluated
Evaluation of A.I. P/F can be where the AI information has been added to a template.
(See Steps 1-8) of this document.