NVLAP Proficiency Test Round 14 Results

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Outline

- PT 14 Structure
  - Lamp Types
  - Lab Participation
  - Format for results
- PT 14 Analysis
  - Average values of labs
  - Average values of lamps
  - Replication results
  - ANOVA
- Conclusions

PT Round 14 Structure -Lamps

- INC: GE E26 based, 120-volt, 53-watt, diffusely coated A-19 type tungsten-halogen from distribution center
  - PT Round 13 used Philips E26 based, 120-volt, 72-watt clear A-19 lamps direct from plant
- CFL: TCP E26 based, 120-volt, 60-hertz, 13-watt, 2700-K spiral design
  - PT Round 13 used same manufacturer and lamp type

PT Round 14 Structure -Lamps

- Labeling
  - Labs assigned a unique randomly selected 2-letter ID (AA through MM)
  - 7 INC lamps packaged for each lab
    - 6 lamps to be analyzed
  - 6 CF lamps packaged for each CFL lab
- Lamps shipped by Fed Ex using TCP facility
  - Joe Marella did all labeling and shipping

PT Round 14 Structure -Labs

- All NVLAP-accredited labs, except those for LM-80 only required to measure Inc lamps
  - 71 labs + NIST (US-36, China-29, Europe-2, Canada-2, South Korea-1, Taiwan-1)
- Only NVLAP labs accredited to LM-66 were required to measure CFL
  - 42 labs + NIST (US-15, China-24, Europe-1, Canada-1, Taiwan-1)

PT Round 14 Structure - Format

- Correspondence by e-mail
- Each lab sent two or three MS Word forms to be filled out and returned with data
  - INC (LM-45)
  - CFL (LM-66) – only to labs with LM-66 in scope
  - Spectroradiometry (LM-58)
- Each lab sent one preformatted MS Excel workbook for filling in data (1 or 2 worksheets)
  - Each lab sent instructions for filling in forms

NVLAP Profiency Test Round 14 Data

Laboratory 2-letter ID: DG NIST

Table A1: Incandescent Lamp Data

please use 2-letter Lab ID with each lamp number below

Color Information is requested for Incandescent lamps

Lamp No.	Replicate	Voltage [volts]	Current [amps]	Power [watts]	Flux [lumens]	Efficacy [lpw]	Color [x]	Color [y]	CCT [K]	Color Rend [Ra]
DG-1	1	120.0	0.4338	52.05	889	17.08	0.4469	0.4047	2,843	99.467
	2	120.0	0.4337	52.04	889	17.08	0.4472	0.4048	2,840	99.465
	3	120.0	0.4337	52.04	889	17.08	0.4471	0.4047	2,841	99.459
Replication Average		**120.0**	**0.4337**	**52.04**	**888.8**	**17.08**	**0.44707**	**0.40474**	**2,841.6**	**99.46**
Replication Variance		**1.94E-05**	**1.51E-09**	**3.80E-05**	**8.80E-02**	**1.35E-05**	**1.55E-08**	**2.51E-09**	**2.30E+00**	**1.64E-05**
Replication % Std Dev		**0.00**	**0.01**	**0.01**	**0.03**	**0.02**	**0.03**	**0.01**	**0.05**	**0.00**
DG-2	1	120.0	0.4316	51.79	860	16.60	0.4489	0.4045	2,812	99.305
	2	120.0	0.4316	51.78	860	16.61	0.4491	0.4046	2,810	99.316
	3	120.0	0.4315	51.78	860	16.60	0.4490	0.4045	2,811	99.311
Replication Average		**120.0**	**0.4316**	**51.79**	**859.9**	**16.60**	**0.44896**	**0.40454**	**2,811.0**	**99.31**
Replication Variance		**1.11E-05**	**9.12E-10**	**2.26E-05**	**2.14E-02**	**5.32E-06**	**9.77E-09**	**2.70E-09**	**1.16E+00**	**2.59E-05**
Replication % Std Dev		**0.00**	**0.01**	**0.01**	**0.02**	**0.01**	**0.02**	**0.01**	**0.04**	**0.01**
DG-3	1	120.0	0.4353	52.24	850	16.26	0.4490	0.4055	2,818	99.496
	2	120.0	0.4353	52.23	849	16.25	0.4492	0.4056	2,816	99.507
	3	120.0	0.4353	52.23	849	16.26	0.4491	0.4055	2,817	99.502
Replication Average		**120.0**	**0.4353**	**52.23**	**849.2**	**16.26**	**0.44906**	**0.40551**	**2,817.1**	**99.50**
Replication Variance		**1.91E-05**	**1.87E-09**	**4.72E-05**	**1.31E-01**	**2.32E-05**	**9.47E-09**	**2.98E-09**	**1.06E+00**	**3.16E-05**
Replication % Std Dev		**0.00**	**0.01**	**0.01**	**0.04**	**0.03**	**0.02**	**0.01**	**0.04**	**0.01**
DG-4	1	120.0	0.4385	52.62	871	16.55	0.4492	0.4051	2,812	99.407
	2	120.0	0.4384	52.61	870	16.55	0.4493	0.4052	2,810	99.411
	3	120.0	0.4384	52.61	870	16.54	0.4493	0.4051	2,810	99.404
Replication Average		**120.0**	**0.4384**	**52.61**	**870.5**	**16.55**	**0.44927**	**0.40512**	**2,810.8**	**99.41**
Replication Variance		**2.89E-05**	**1.26E-09**	**4.01E-05**	**7.39E-02**	**1.17E-05**	**7.17E-09**	**2.11E-09**	**8.28E-01**	**1.16E-05**
Replication % Std Dev		**0.00**	**0.01**	**0.01**	**0.03**	**0.02**	**0.02**	**0.01**	**0.03**	**0.00**
DG-5	1	120.0	0.4418	53.01	885	16.70	0.4479	0.4053	2,833	99.526
	2	120.0	0.4418	53.01	885	16.70	0.4479	0.4053	2,833	99.522
	3	120.0	0.4416	52.99	884	16.68	0.4479	0.4053	2,833	99.525
Replication Average		**120.0**	**0.4418**	**53.01**	**884.8**	**16.69**	**0.44793**	**0.40527**	**2,832.7**	**99.52**
Replication Variance		**4.31E-06**	**8.65E-09**	**1.11E-04**	**6.61E-01**	**1.45E-04**	**9.63E-11**	**3.55E-11**	**2.38E-02**	**3.35E-06**
Replication % Std Dev		**0.00**	**0.02**	**0.02**	**0.09**	**0.07**	**0.00**	**0.00**	**0.01**	**0.00**
DG-6	1	120.0	0.4410	52.93	871	16.46	0.4494	0.4041	2,801	99.198
	2	120.0	0.4408	52.92	871	16.45	0.4494	0.4041	2,801	99.188
	3	120.0	0.4408	52.89	870	16.44	0.4494	0.4041	2,801	99.187
Replication Average		**120.0**	**0.4409**	**52.91**	**870.5**	**16.45**	**0.44938**	**0.40407**	**2,800.9**	**99.19**
Replication Variance		**6.05E-04**	**8.12E-09**	**4.32E-04**	**5.42E-01**	**5.65E-05**	**7.45E-10**	**6.52E-10**	**4.34E-02**	**3.99E-05**
Replication % Std Dev		**0.02**	**0.02**	**0.04**	**0.08**	**0.05**	**0.01**	**0.01**	**0.01**	**0.01**
DG-7	1	120.0	0.4342	52.09	860	16.50	0.4488	0.4051	2,818	99.432
	2	120.0	0.4341	52.09	859	16.50	0.4487	0.4050	2,818	99.417
	3	120.0	0.4341	52.09	859	16.49	0.4487	0.4050	2,818	99.416
Replication Average		**120.0**	**0.4341**	**52.09**	**859.4**	**16.50**	**0.44875**	**0.40503**	**2,818.1**	**99.42**
Replication Variance		**1.52E-05**	**1.92E-09**	**1.28E-05**	**1.08E-01**	**2.68E-05**	**2.04E-09**	**8.18E-10**	**2.06E-01**	**7.41E-05**
Replication % Std Dev		**0.00**	**0.01**	**0.01**	**0.04**	**0.03**	**0.01**	**0.01**	**0.02**	**0.01**
Lab Average All Measurements		**120.0**	**0.4369**	**52.43**	**870.6**	**16.60**	**0.4486**	**0.4049**	**2,819.0**	**99.40**
Total Variance		**1.20E-04**	**1.46E-05**	**2.12E-01**	**1.95E+02**	**6.69E-02**	**7.46E-07**	**2.47E-07**	**2.06E+02**	**1.44E-02**
Total Std Dev		**0.01**	**0.0038**	**0.46**	**14.0**	**0.26**	**0.0009**	**0.0005**	**14.3**	**0.12**
Total % Std Dev		**0.01**	**0.88**	**0.88**	**1.61**	**1.56**	**0.19**	**0.12**	**0.51**	**0.12**
Rep Variance		**1.15E-04**	**3.72E-09**	**1.15E-04**	**2.53E-01**	**4.25E-05**	**7.13E-09**	**1.83E-09**	**9.03E-01**	**2.15E-05**
Rep Std Dev		**0.01**	**0.0001**	**0.01**	**0.50**	**0.01**	**0.0001**	**0.0000**	**0.95**	**0.00**
Rep % Std Dev		**0.01**	**0.01**	**0.02**	**0.06**	**0.04**	**0.02**	**0.01**	**0.03**	**0.00**
Lamp Varaince		**1.34E-04**	**4.97E-05**	**7.20E-01**	**6.64E+02**	**2.27E-01**	**2.52E-06**	**8.34E-07**	**6.97E+02**	**4.89E-02**
Lamp Std Dev		**0.01**	**0.01**	**0.85**	**25.8**	**0.48**	**0.0016**	**0.0009**	**26.4**	**0.22**
Lamp % Std Dev		**0.01**	**1.61**	**1.62**	**2.96**	**2.87**	**0.35**	**0.23**	**0.94**	**0.22**

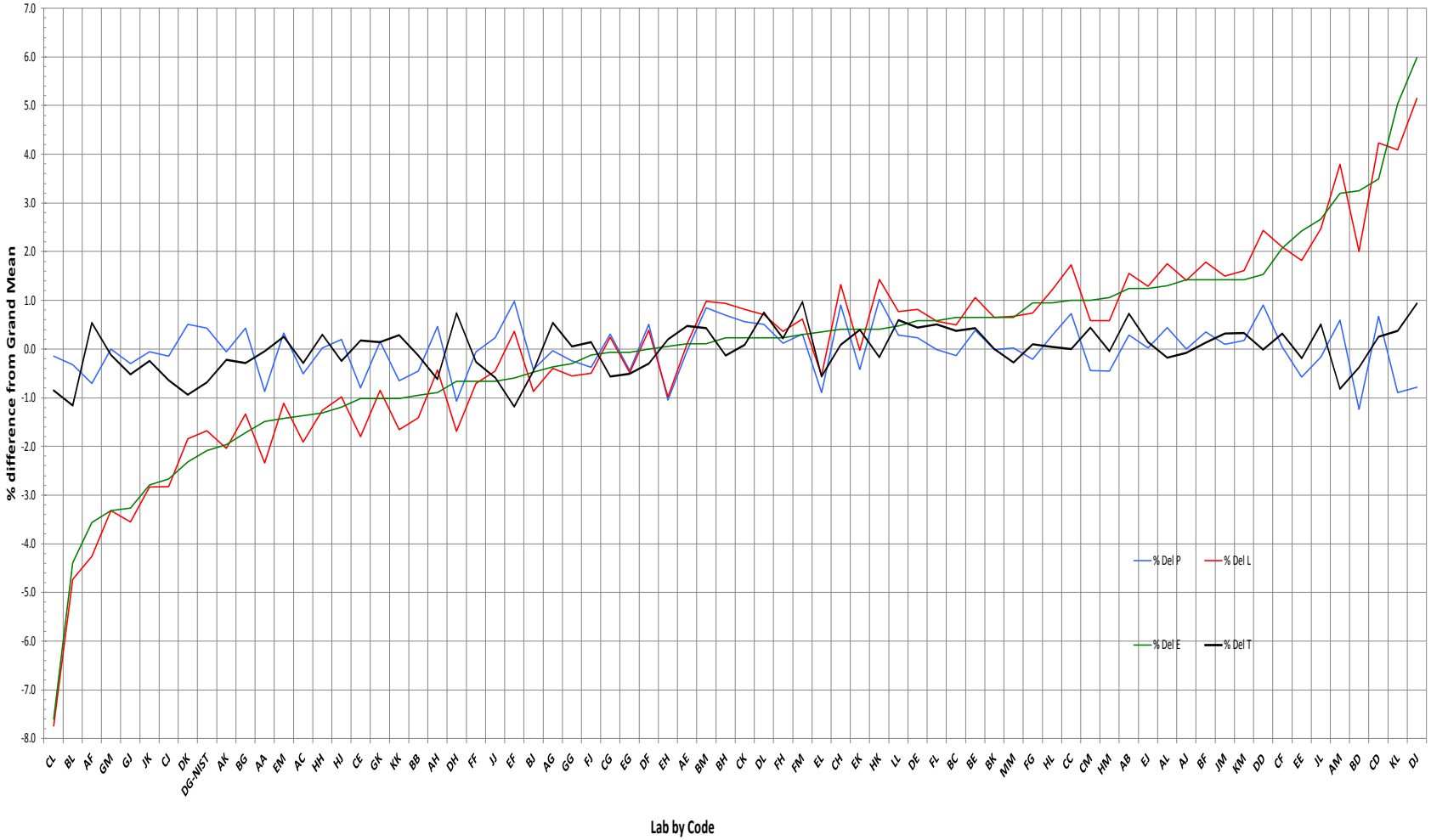
PT Round 14 – Documentation

- Written document: Tech Brief
- Excel Workbooks for both INC and CFL
  - Collected Lab Data
    - Workbook with each lab's data on a worksheet labeled by ID
  - Lab Average Analysis
    - Workbook with all lab average data sorted by Average Efficacy, Normal Distribution plots and Z-scores
  - Lab Variance Analysis
    - Workbook with lamp and replication averages
  - ANOVA

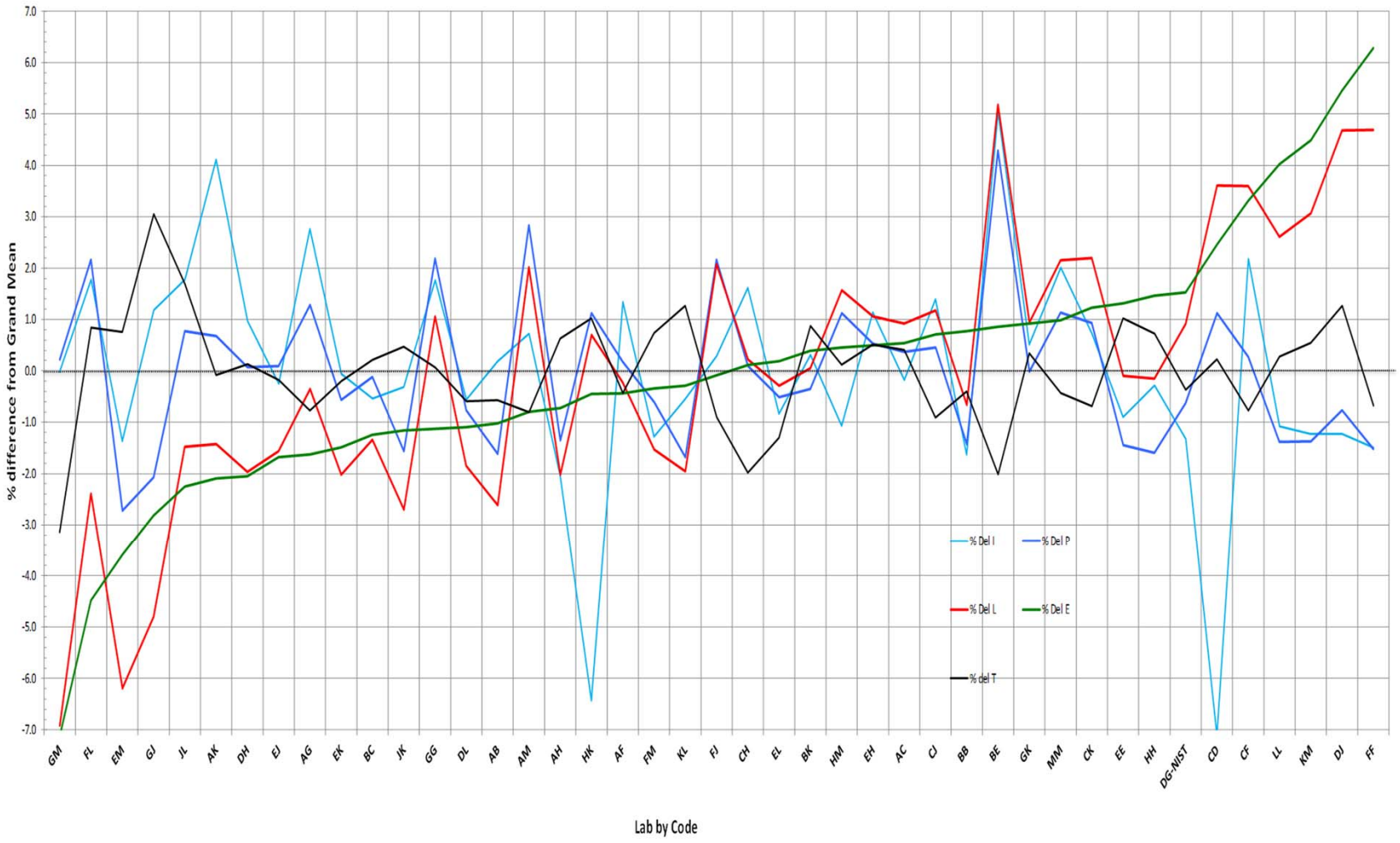
PT Round 14 – Average Analysis

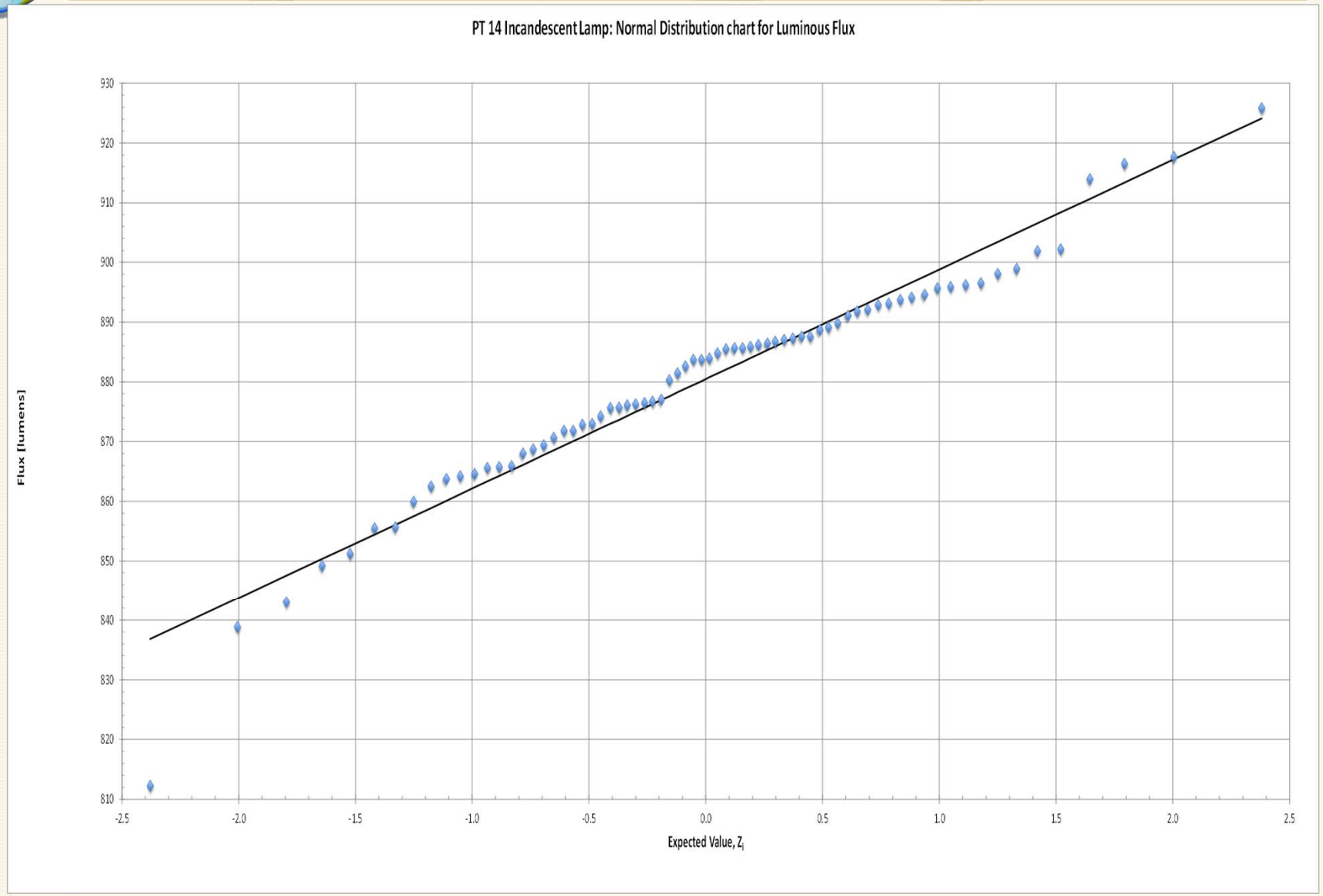
- All lab Average, Variance, Std. Dev. and % Std. Dev. for each variable measured
- Lab distribution chart for Power, Lumens, Efficacy and CCT sorted by increasing Lumen Efficacy
- Normal distribution charts for all variables
- Lab Z-scores for each variable identifying outlier or potential problem labs
  - Outlier labs for Z < -3.0 or > +3.0
  - Potential problem labs for Z between +/- 2 and +/- 3

PT 14 Incandescent Lamp: % change in lab values for power, lumens, efficacy & CCT vs. Grand Mean - sorted by increasing efficacy



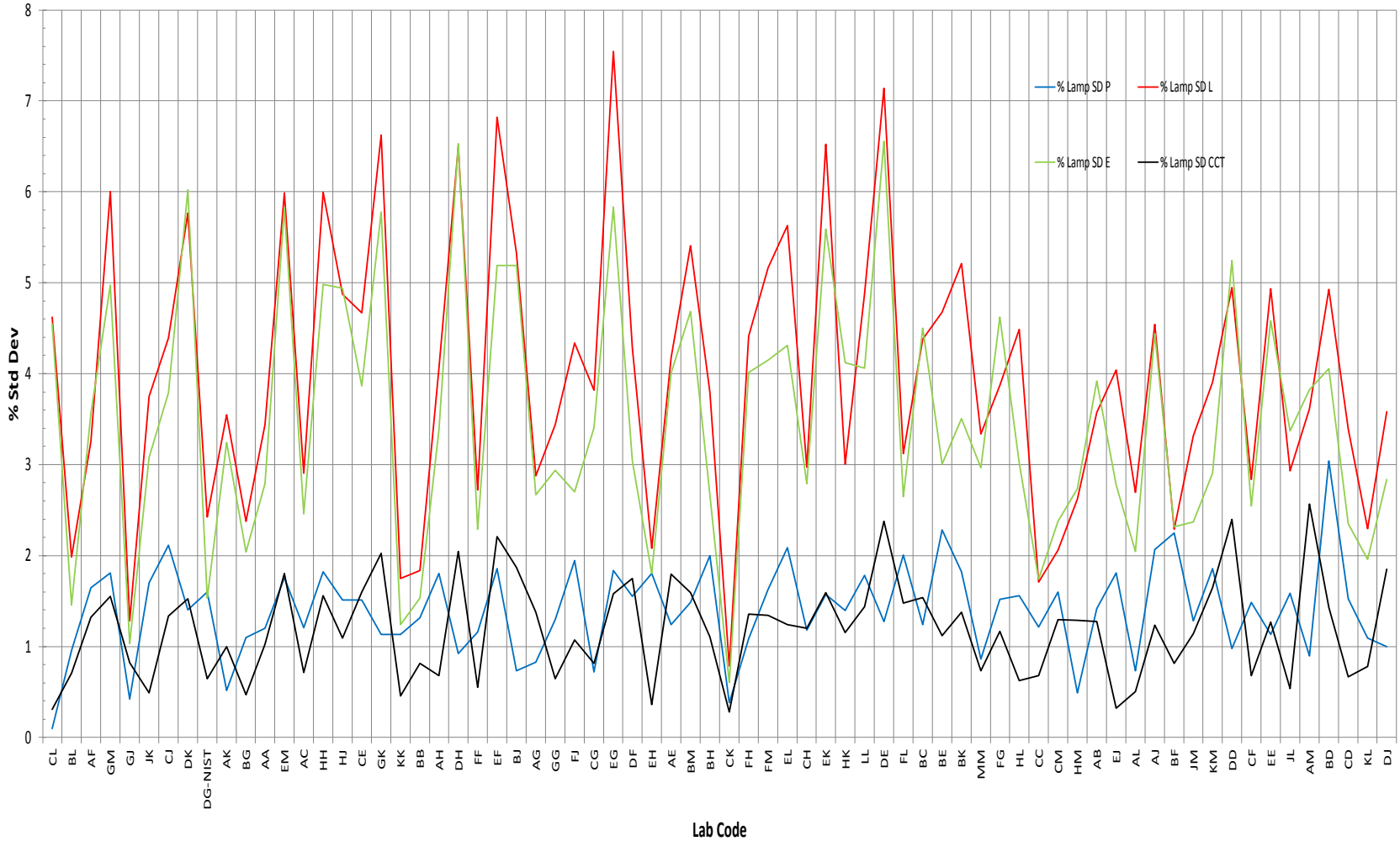
PT 14 CFL: % change in lab values for current, power, lumens, efficacy & CCT vs. Grand Mean - sorted by increasing efficacy

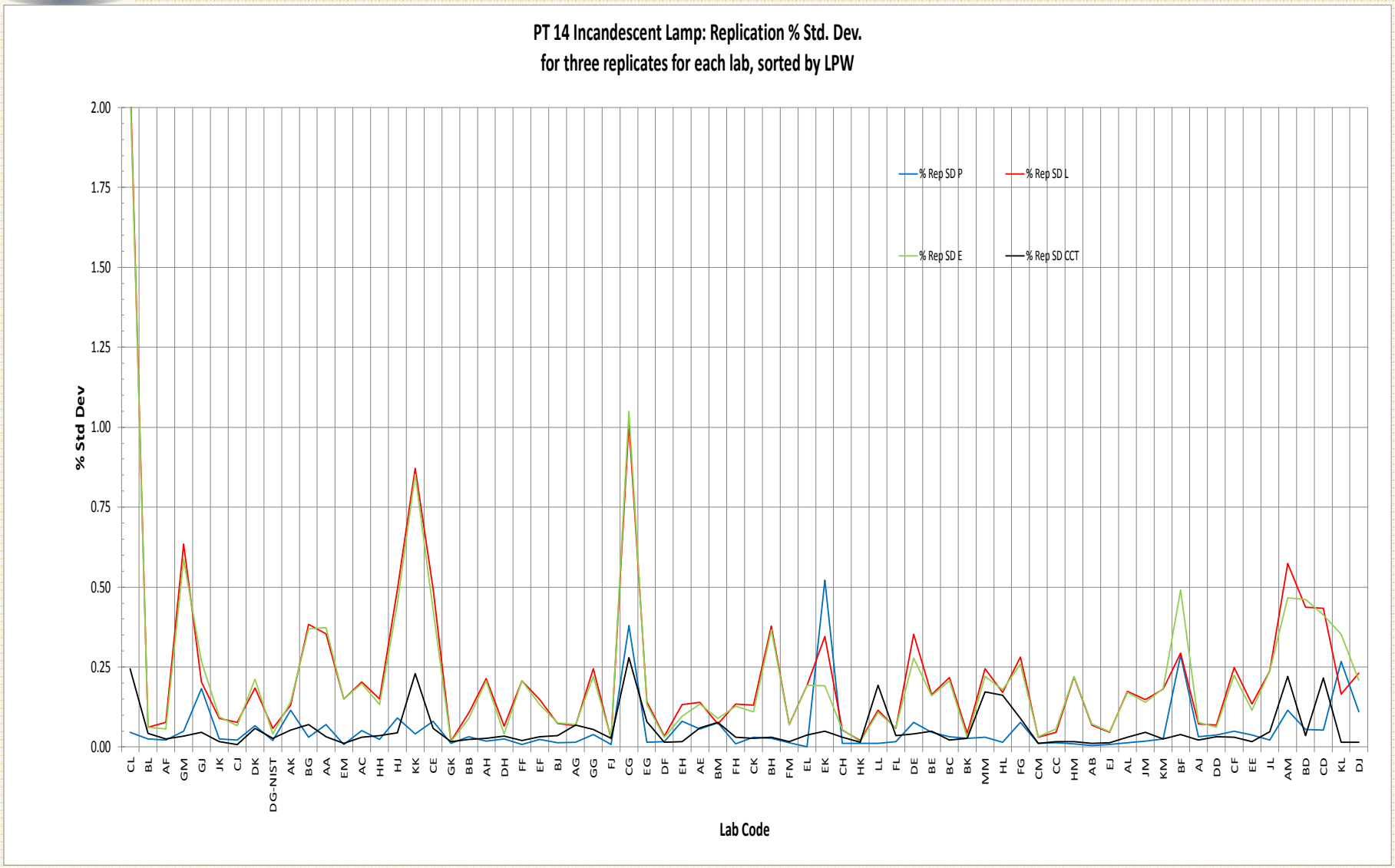


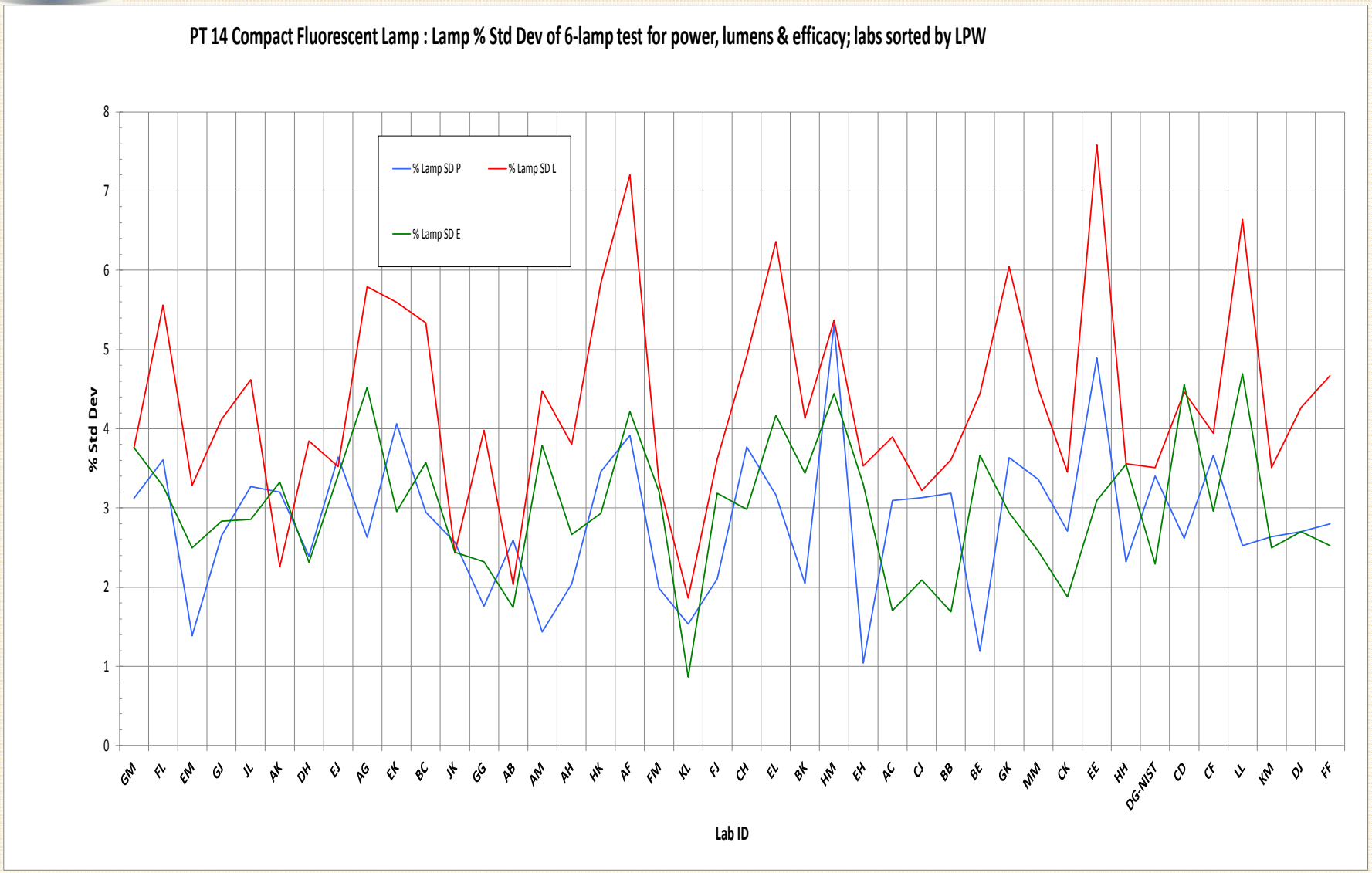

PT 14 Incandescent Lamp: Normal Distribution chart for Luminous Flux
Flux [lumens]
930
920
910
900
890
880
870
860
850
840
830
820
810
-2.5
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
2.5
Expected Value, Z_i

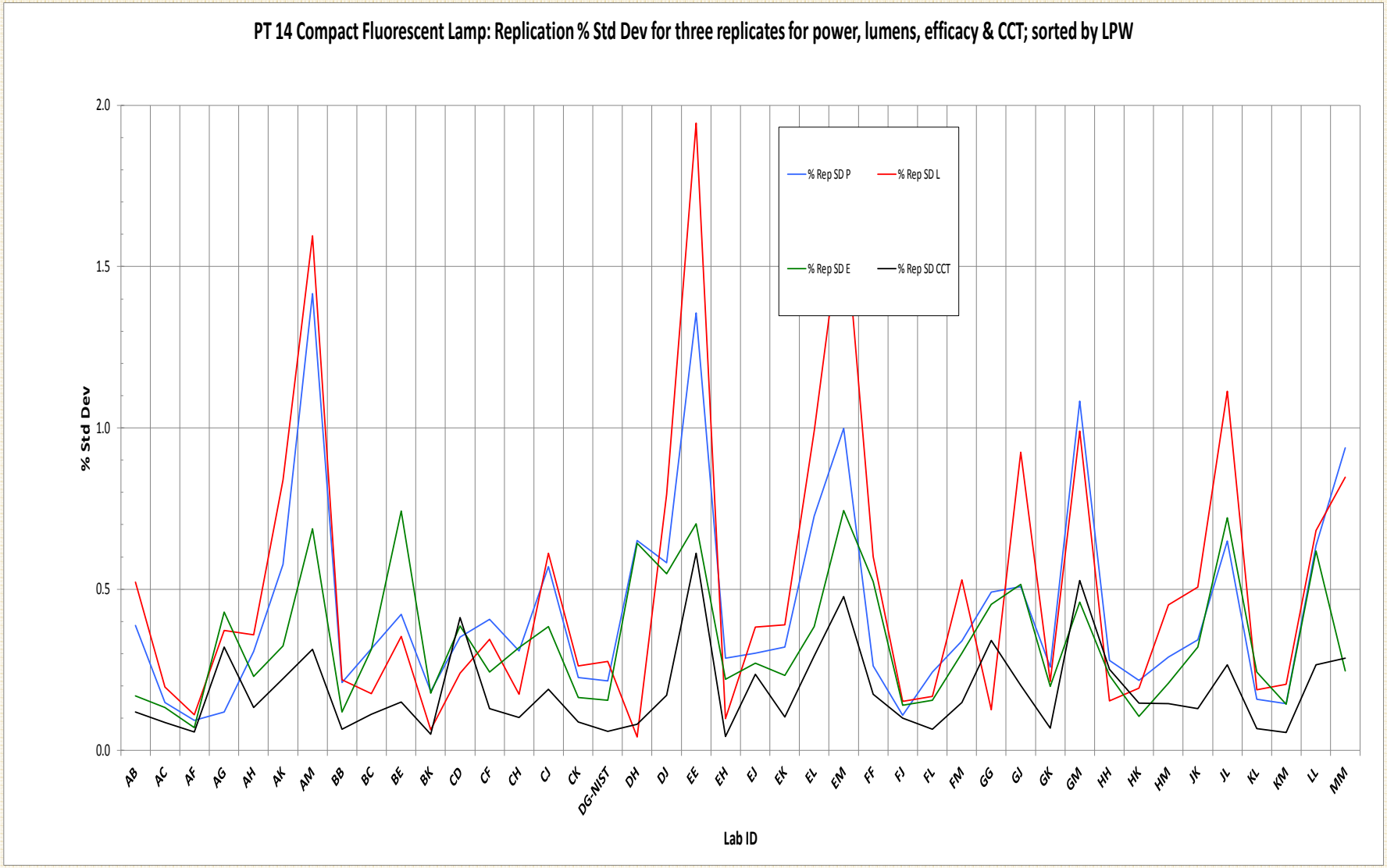
PT Round 14 – Variance Analysis

- Calculate Std. Dev. and % Std. Dev.
- Use % Std. Dev. as comparison indicator
- Lab Variance
  - Averaged over 18 measurements per lab per variable
- Lamp Variance
  - Average from individual lab variance of 6 lamps
  - Lamp variance of 6 lamps
- Replication Variance


PT 14 Incandescent Lamp: Lamp % Std. Dev. of 6-lamp test
for power, lumens efficacy & CCT for each lab; sorted by LPW
% Lamp SD P
% Lamp SD L
% Lamp SD E
% Lamp SD CCT
% Std Dev
0
1
2
3
4
5
6
7
8
CL BL AF GM GJ JK CJ DK DG-NIST AK BG AA EM AC HH HJ CE GK KK BB AH DH FF EF BJ AG GG FJ CG EG DF EH AE BM BH CK FH FM EL CH EK HK LL DE FL BC BE BK MM FG HL CC CM HM AB EJ AL AJ BF JM KM DD CF EE JL AM BD CD KL DJ
Lab Code


PT 14 Incandescent Lamp: Replication % Std. Dev.
for three replicates for each lab, sorted by LPW
% Rep SD P
% Rep SD L
% Rep SD E
% Rep SD CCT
% Std Dev
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
CL BL AF GM GJ JK CJ DK DG-NIST AK BG AA EM AC HH HJ KK CE GK BB AH DH FF EF BJ AG GG FJ CG EG DF EH AE BM FH CK BH FM EL EK CH HK LL FL DE BE BC BK MM HL FG CM CC HM AB EJ AL JM KM BF AJ DD CF EE JL AM BD CD KL DJ
Lab Code


PT 14 Compact Fluorescent Lamp : Lamp % Std Dev of 6-lamp test for power, lumens & efficacy; labs sorted by LPW
% Lamp SD P
% Lamp SD L
% Lamp SD E
% Std Dev
0
1
2
3
4
5
6
7
8
GM FL EM GI JL AK DH EJ AG EK BC JK GG AB AM AH HK AF FM KL FJ CH EL BK HM EH AC CJ BB BE GK MM CK EE HH DG-NIST CD CF LL KM DJ FF
Lab ID


PT 14 Compact Fluorescent Lamp: Replication % Std Dev for three replicates for power, lumens, efficacy & CCT; sorted by LPW
% Rep SD P
% Rep SD L
% Rep SD E
% Rep SD CCT
% Std Dev
2.0
1.5
1.0
0.5
0.0
AB AC AF AG AH AK AM BB BC BE BK CD CF CH CJ CK DG-NIST DH DJ EE EH EJ EK EL EM FF FJ FL FM GG GJ GK GM HH HK HM JK JL KL KM LL MM
Lab ID

PT Round 14 - ANOVA

- Two-factor ANOVA with replication was run using Excel Analysis tools
  - Requires lab data for each factor to be formatted in 3 rows and 6 columns
  - Copying of data piece-by-piece was necessary as lab data sheet not structured for ANOVA
  - Did ANOVA for INC Lumen Output and Efficacy
  - Did ANOVA for CFL Power, Lumen Output and Efficacy
  - Manipulation of ANOVA results done to show equality

ANOVA Results for 70 INC labs

	Total						
Count	210	210	210	210	210	210	18
Sum	3527.9	3541.6	3558.1	3547.8	3539.2	3531.0	305.5
Average	16.80	16.86	16.94	16.89	16.85	16.81	16.97
Variance	0.210	0.245	0.208	0.215	0.256	0.230	0.075

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit	
Sample	150.0	69	2.174	606.6	0	1.31	
Columns	2.921	5	0.584	163.0	4.5723E-121	2.22	
Interaction	132.0	345	0.383	106.7	0	1.16	0.385
Within	3.011	840	0.004				0.621
Total	288.0	1259					3.658

Calculations based on ANIOVA MS values

	Variance	Std Dev	% Std Dev	Average from Analysis	Comp % std dev
Sample	0.1208	1.475	8.69	2.04	2.05
Columns		0.764	4.50	3.45	3.66
Interaction		0.619	3.64		
Within		0.060	0.35	0.35	
6 lamps				1.41	1.49

ANOVA Summary: 42 CFL labs

	Total						
Count	126	126	126	126	126	126	
Sum	8554.08	8583.46	8568.13	8600.53	8583.92	8583.54	
Average	67.89	68.12	68.00	68.26	68.13	68.12	68.09
Variance	4.14	5.54	3.75	2.61	4.48	4.17	4.11
% Std Dev	2.99	3.46	2.84	2.37	3.11	3.00	2.96

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit	
Sample	2114.96	41	51.5845	606.54	0	1.413	
Columns	10.06	5	2.0116	23.65	2.2E-21	2.232	
Interaction	927.56	205	4.5247	53.20	2E-253	1.207	4.465
Within	42.86	504	0.0850				2.113
Total	3095.44	755					3.10

Calculations

	Std Dev	% Std Dev	Average from Analysis	Comp % std dev
Sample	7.18	10.55	2.49	2.49
Columns	1.42	2.08	3.01	3.10
Interaction	2.13	3.12		
Within	0.29	0.43	0.39	
6 lamps			1.23	1.27

PT Round 14 – Conclusions, INC

- Incandescent lamps used not an ideal vehicle for test
  - Lamp Standard Deviation for INC was 4 to 5 times higher than that for PT 13 INC
  - Lamp variability averaged over 6 lamps was smaller than lab variability so statistics are considered valid and therefore a Z-score of less than or equal to -3, or greater than or equal to +3,is used to define outliers.
  - 95 % confidence in defining lab rank or actual values for lumens and efficacy has a +/- 3 % uncertainty

PT Round 14 – Conclusions, CFL

- CFLs used, which were same type as PT 13, not an ideal vehicle for test
  - Lamp Standard Deviation for CFL was almost a factor of 2 times higher than that for PT 13 INC
  - Lamp variability averaged over 6 lamps was smaller than lab variability so statistics are considered valid and therefore a Z-score of less than or equal to -3, or greater than or equal to +3, is used to define outliers.
  - 95 % confidence in defining lab rank or actual values for lumens and efficacy has a +/- 2.5 % uncertainty

PT Round 14 – Issues

- Due to large incandescent lamp uncertainty it is difficult to judge if the industry is getting better
- Do we continue Incandescent lamps or CFL for future PTs?
  - Cost is about $1 k per lab, results in 8 months
  - Manufacturers are not putting any engineering into Incandescent and CFL product has larger uncertainty; also difficult to get commitment to making a batch for NVLAP as manufacturing not done in US

PT Round 14 – Issues (cont.)

- One solution is to go back to a multiple round robin of 3 to 4 labs
  - Better comparisons with less uncertainty
  - Will add 6 months to PT
  - Broken lamps will cause gaps

PT Round 14 – Issues LEDs

- Currently NIST is doing SSL bilateral PT with NVLAP Labs.
  - Will that continue in the future?
  - Labs get a direct comparison to NIST; lower uncertainty
  - Cost is $3k, takes 4 yrs. to complete
- Should LED lamps be used for general PT?
  - Costs have come down to where they are competitive.
  - Handling reliability is better than incandescent lamps
  - Lamp-to-lamp variability and reproducibility a large issue