10 January, 2008

Norbert and Dennis,

In an earlier message, (E-mail on 12/19/07), in connection with the Mk.2A 6x97 matrix, I had written:

> *I do have some doubts about the integrity of the full 6x97 matrix since I see in it some terms that seem unreasonably large (and tend to cancel), and you have confirmed that your ANOVA results suggest some 'near singularities' when the load design is applied to the full 6x97 model. So I would agree that a matrix for which the math model does not show such linear dependencies would be a safer choice to use for a test. Whether the best choice is the "optimum matrix" as you have defined it, is something I'd like to discuss further with you - frankly I'm a bit disturbed to see terms being discarded purely on the basis of a statistical assessment of a single calibration dataset, and seemingly without consideration of the physical reasoning for their presence in the model in the first place. I intend to take a look at some other models, based on the term exclusions that you have identified but moderated by retaining (or rejecting) ALL terms that are 'related to each other' by the physical reasoning for their presence….*
>
> *I will send you a fuller explanation of my concerns after I've had a chance to examine some results with other models ….*

The phrase highlighted in red is what concerns me about the way in which BALFIT's math model term selection process is implemented, but I hasten to add that I am 100% in favour of the objective, namely the indentification and removal of terms in the math model that are unsupported, or inadequately supported, by the calibration load design.

The basis of my concern lies in the fact that the 97-term equation, (i.e. 96 load terms + intercept), seemingly has come to be viewed as the fundamental representation of the balance's load/response relationship, whereas I consider the fundamental representation as being that expressed by Eqn. 3.1.2 in R-091-2003, namely:

$$R_i = a_i + \sum_{j=1}^{n} b_{i,j} F_j + \sum_{j=1}^{n} \sum_{k=j}^{n} c_{i,j,k} F_j F_k + \sum_{j=1}^{n} d_{i,j} F_j^3$$

This 'generally accepted' model comprises an intercept term and, for a 6-component balance, 33 'load' terms in Fj, Fj^2, Fj.Fk, and Fj^3. It can be made to account for possible asymmetric load effects by allowing each of the Fj, Fj^2 and Fj^3 terms to take one of two values according to the sign of the load Fj, and each of the Fj.Fk terms to take 1 of 4 values according to the signs of the loads in the product Fj.Fk, (+/+, +/-, -/+ and -/-). Prior to the introduction of the 97-term math model representation in R-091-2003, multiple values for the various coefficients traditionally were determined for each load sign, or load sign combination, using procedures similar to the 'piece-wise curve-fitting' process described in Cook's paper, and also in my LR-600. Then, when calculating the loads equivalent to a particular vector of strain gauge bridge responses, the calibration matrix would be 'synthesized' by selecting its coefficients according to the signs of the loads, which initially were taken to be the same as the signs of the bridge responses. Occasionally this process would result in one or more of the computed loads having a sign different to that which had been used in the coefficient selection process, and in that case a new matrix would be selected based on the signs of the computed loads, and the loads calculation repeated. Such iteration was usually only required for loads that were close to zero, where interactions could lead to the load and the bridge response having different signs.

This is the model that essentially all of the members of the original AIAA 'Balance' WG already used and accepted. Some used a 6x27 model (no load cubed terms) instead of 6x33, and some determined coefficients as a function of load sign while some others did not, but I think all accepted that for some balances, (e.g. the 'Task' design), there were indeed potential slope discontinuities either side of zero load. In fact I recall Andy Garrell as saying that, because they (Calspan) needed to determine different coefficients based on the sign(s) of the loads, they did not use global regression because they couldn't determine the separate coefficients that way. **That was the point at which I pointed out that the asymmetric load behaviour could be modeled by the (now ubiquitous) 97-term equation to which global regression could be applied, and the 6x96 (or 6x97) matrix was born!!**

In hindsight I regret that, in what I wrote for the RP document, I did not place more emphasis on the fact that the function of the additional 'absolute value' terms is only to MODIFY the effect of the fundamental 'signed' terms. Consequently I consider it necessary that either ALL or NONE of the terms that modify a particular original 'signed' term must be present in the math model. Using the load product "N1.N2" as an example, the 'signed' term in the original 6x33 model is "N1.N2", and the three additional 'modifying' terms in the 97-term model are "|N1.N2|", "N1.|N2|" and |N1|.N2". It is my opinion that, to properly account for asymmetric load behaviour, all 4 of these terms must be present in the math model since there is not a 1:1 relationship between the +/+, +/-, -/+

and -/- coefficients obtainable by a 'piece-wise curve-fitting' technique, and the coefficients of "N1.N2", "|N1.N2|", "N1.|N2|" and |N1|.N2" in the 97-term math model. While the observed physical load/response characteristic of the balance, (that sensitivities to positive and negative load can be different), can be properly modeled by selecting specific coefficients from those for the + or -, or +/+, +/-, -/+ or -/-, signs of load or load combination, the same is not true for the 'absolute value' coefficients of the 97-term model. Only by utilizing ALL of the "N1.N2", "|N1.N2|", "N1.|N2|" and |N1|.N2" terms together is the effect of a particular load product sign combination modeled correctly, by effectively selecting from the 4 possible 'N1.N2' load product coefficients the one that is appropriate to the particular signs of Fj and Fk. It is for this reason that I'm uneasy about the way in which BALFIT's math model search algorithm is implemented, since it allows each of the "N1.N2", "|N1.N2|", "N1.|N2|" and |N1|.N2" terms to be assessed, and possibly excluded from the math model, independently of the others. I contend that, if any of those 4 terms are missing then the effects of load sign, i.e. sign of strain in the measuring elements, are not being modeled as the fundamental 6x33 math model intended. Of course, if no account is taken of asymmetric load behaviour, then only the 'signed' term, and NONE of the 3 terms involving 'absolute values', should be present in the math model, and in this case the 'signed' term can obviously be assessed on its own, both for proper definition by the loading design and significance to the result.

I would be most interested to see the 'math model term selection' results for the Mk.2A balance that would be produced if a modification were made to BALFIT's math model search algorithm to impose the following additional constraint. For each component in each of these 4 term groups, (not, I suggest, 10 separate 'groups' of terms as is frequently referred to in the AIAA papers you sent me),

$$\{ Fj \;\&\; |Fj| \}, \qquad \{ Fj^2 \;\&\; Fj.|Fj| \}, \qquad \{ Fj.Fk, |Fj.Fk|, Fj.|Fk| \;\&\; |Fj|.Fk \}, \qquad \{ Fj^3 \;\&\; |Fj^3| \}$$

the coefficients must either ALL BE PRESENT, or that ONLY the coefficients of the 'signed' terms, (Fj, Fj^2, Fj.Fk and Fj^3), should be present, (assuming they are properly defined by the loading design and are statistically significant). Such a modification would reduce the number of models to be assessed, shortening the computation process.

Using the NASA Ames Mk.2A data I have made some experiments along these lines, starting with BALFIT's "optimum" {52, 42, 38, 37, 32, 50} matrix but then imposing the above type of constraint. I have tried six different matrices, all obtained by excluding and/or including terms (relative to the "optimum" model) in several combinations. Generally these matrices contain even fewer terms than BALFIT's "optimum" matrix, but for most of the components several of these modified matrices actually giver lower error standard deviations for the Manual Check Loads and 6-comp. W/T Test Loads data files than the "optimum" matrix does. In the case of the back-calculation of the 'parent' calibration loads used to generate the matrices, (File 07), the error standard deviations are a measure of how well the selected model fits the data, and the matrix with the largest number of terms will usually give the lowest standard deviations. Consequently the standard deviations obtained with my modified matrices tend to be slightly higher than those obtained with the "optimum" matrix, and the full 6x97 matrix typically produces the lowest values. I think the results are sufficiently interesting to warrant further investigation.

A description of how the terms were selected for the six modified matrices, together with summarized statistics for nine different matrices, (6x97, 6x85, BALFIT's "optimum", and the 6 modifications based on the optimum), are given below. The results obtained for all matrices when computing the loads for each data file are initially shown on a single page, one page for each of files 07 (calibration data), 06 (manual loads data), and 03 (6-component W/T Test Loads data). Following that, the same results are presented at a larger scale with just one tabulation or plot per page. In the plots, the standard deviations are shown normalized by the smallest value and expressed as a percentage, i.e. the smallest standard deviation equals 100.

Finally, I should note that the standard deviation formula I have used employs the actual average error, and that the various statistics presented are based on ALL data points in each file, not just the 'non-zero load' points. I believe that a valid assessment of matrix performance should include all points and not just those points for which the load on the component under consideration is non-zero. Non-zero loads on the other components will cause interactions, and it is necessary to assess how well the matrix accounts for these. In my view 'zero' load is just another load, and so long as some of the components experience non-zero load I feel the error result for that condition should be included when assessing matrix performance. For points where ALL components are subjected to zero load, then there may be justification for excluding such points from the statistics so as to avoid giving undue weight to a condition which may be frequently repeated in some manually-loaded calibrations. However, for machine-loaded calibrations where load 'zeros' are unlikely to be either equal to zero or repeated precisely, I really see no need to exclude points that represent nominal zero load conditions for all components.

I will be most interested to have your feedback on my comments and the enclosed results.

Cheers, Robin

Matrix ID	
1	Full 6 x 97 math model as in AIAA R-091-2003
2	6 x 85 math model = matrix "1" with the load cubed, (F^3 and $|F^3|$), terms excluded (set to zero)
3	Norbert Ulbrich's "optimum" matrix from BALFIT's automatic term selection algorithm, terms/component = {52, 42, 38, 37, 32, 50}
4	Matrix with { 32, 28, 26, 14, 17, 27} terms/component, based on matrix "3" but modified as follows: a) for the F, |F|, F^2, F.|F|, F^3 and |F^3|, set to zero all "absolute value" terms for which the corresponding "signed" term in "3" is zero, b) for the 2-load cross-product terms, set to zero all "absolute value" terms for which the corresponding "signed" product term in "3" is zero, c) for the 2-load cross-product terms, if the "signed" product term in "3" is non-zero then set to zero all "absolute value" terms if any of those 3 terms is zero.
5	Matrix with { 38, 26, 32, 24, 19, 31} terms/component, based on matrix "3" but modified as follows: a) for the F and |F| terms, INCLUDE those terms for which both the "signed" and "absolute value" terms in "3" are zero, b) for the F^2 and F.|F| terms, INCLUDE any "signed" terms that are zero in "3", but for which the "absolute value" terms are non-zero, c) for the F^3 and |F^3|, zero ALL terms, d) for the 2-load cross-product terms, set to zero all "absolute value" terms for which the corresponding "signed" product term in "3" is zero, e) for the 2-load cross-product terms, if the "signed" product term in "3" is non-zero then set to zero all "absolute value" terms if any of those 3 terms is zero.
6	Matrix with { 36, 26, 30, 20, 15, 31} terms/component, based on matrix "3" but modified as follows: a) for the F^2 and F.|F| terms, INCLUDE any "signed" terms that are zero in "3", but for which the "absolute value" terms are non-zero, b) for the F^3 and |F^3|, zero ALL terms, c) for the 2-load cross-product terms, set to zero all "absolute value" terms for which the corresponding "signed" product term in "3" is zero, d) for the 2-load cross-product terms, if the "signed" product term in "3" is non-zero then set to zero all "absolute value" terms if any of those 3 terms is zero.
7	Matrix with { 36, 28, 26, 22, 17, 27} terms/component, based on matrix "3" but modified as follows: a) for the F, |F|, F^2, F.|F|, F^3 and |F^3|, set to zero all "absolute value" terms for which the corresponding "signed" term in "3" is zero, b) for the 2-load cross-product terms, set to zero the "absolute value" terms unless ALL 3 "absolute value" terms in "3" are non-zero, in which case INCLUDE ALL 4 cross-product terms, even if the "signed" cross-product term in "3" is zero.
8	Matrix with { 50, 37, 32, 33, 20, 47} terms/component, based on matrix "3" but modified as follows: a) for the F, |F|, F^2, F.|F|, F^3 and |F^3|, set to zero all "absolute value" terms for which the corresponding "signed" term in "3" is zero, b) for the 2-load cross-product terms, set to zero the "absolute value" terms unless AT LEAST 2 "absolute value" terms in "3" are non-zero, in which case INCLUDE ALL 4 cross-product terms, even if the "signed" cross-product term in "3" is zero.
9	Matrix with { 60, 54, 50, 54, 60, 63} terms/component, based on matrix "3" but modified as follows: a) for the F, |F|, F^2, F.|F|, F^3 and |F^3|, set to zero all "absolute value" terms for which the corresponding "signed" term in "3" is zero, b) for the 2-load cross-product terms, set to zero the "absolute value" terms unless AT LEAST 1 "absolute value" terms in "3" is non-zero, in which case INCLUDE ALL 4 cross-product terms, even if the "signed" cross-product term in "3" is zero.

Error statistics summary from loads calculation of the Mk.2A Calibration Loads File 07 using different matrices.

Matrix "1" (6x97)	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.362	1.238	0.584	2.282	4.056	0.379
MIN error %FS	-0.472	-0.998	-0.770	-2.517	-3.023	-0.384
Absolute largest error %FS	0.472	1.238	0.770	2.517	4.056	0.384
Std. Devn. %FS	0.066	0.274	0.145	0.651	0.663	0.114
Average error %FS	0.000	0.000	0.000	-0.003	0.000	0.000
Ratio of absolute largest error to Std. Devn.	7.13	4.52	5.32	3.86	6.11	3.36
# terms	97	97	97	97	97	97

Matrix "2" (6x85)	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.430	1.153	0.597	2.186	4.217	0.371
MIN error %FS	-0.437	-0.582	-0.752	-2.340	-3.240	-0.379
Absolute largest error %FS	0.437	1.153	0.752	2.340	4.217	0.379
Std. Devn. %FS	0.070	0.272	0.147	0.647	0.662	0.114
Average error %FS	0.000	0.000	0.000	-0.002	-0.001	0.000
Ratio of absolute largest error to Std. Devn.	6.28	4.24	5.12	3.62	6.37	3.32
# terms	85	85	85	85	85	85

Matrix "3" (Norbert Ulbrich "optimum")	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.404	1.207	0.521	2.199	4.222	0.376
MIN error %FS	-0.414	-1.058	-0.713	-2.351	-3.384	-0.404
Absolute largest error %FS	0.414	1.207	0.713	2.351	4.222	0.404
Std. Devn. %FS	0.073	0.278	0.163	0.699	0.671	0.116
Average error %FS	0.000	0.000	-0.001	-0.003	-0.001	0.000
Ratio of absolute largest error to Std. Devn.	5.69	4.34	4.37	3.38	6.29	3.49
# terms	52	42	38	37	32	50

Matrix "4" (Mod-A of "optimum")	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.481	1.355	0.593	2.514	5.175	0.531
MIN error %FS	-0.390	-1.032	-0.623	-2.995	-3.325	-0.437
Absolute largest error %FS	0.481	1.355	0.623	2.995	5.175	0.531
Std. Devn. %FS	0.087	0.295	0.180	0.827	0.763	0.142
Average error %FS	0.000	0.000	-0.001	-0.003	0.000	0.000
Ratio of absolute largest error to Std. Devn.	5.54	4.60	3.46	3.62	6.78	3.70
# terms	32	28	26	14	17	27

Matrix "5" (Mod-A2 of "optimum")	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.543	1.251	0.581	2.256	4.703	0.504
MIN error %FS	-0.362	-0.915	-0.634	-2.715	-3.312	-0.426
Absolute largest error %FS	0.543	1.251	0.634	2.715	4.703	0.504
Std. Devn. %FS	0.085	0.295	0.160	0.779	0.758	0.136
Average error %FS	0.000	0.000	-0.001	-0.004	0.000	0.000
Ratio of absolute largest error to Std. Devn.	6.37	4.24	3.96	3.48	6.20	3.72
# terms	38	26	32	24	19	31

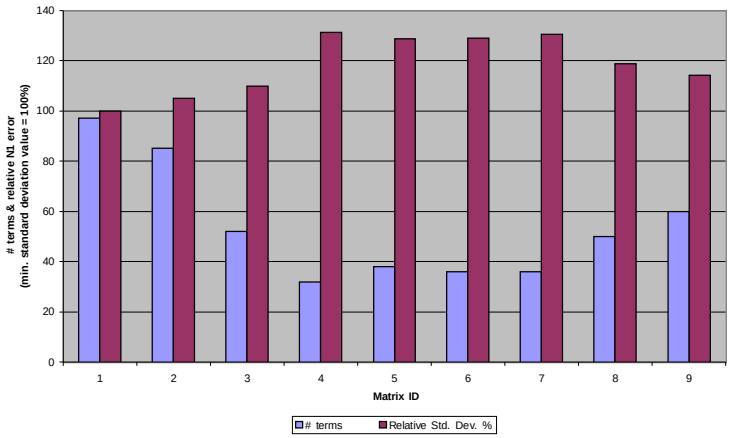
Matrix "6" (Mod-A3 of "optimum")	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.545	1.249	0.584	2.195	4.785	0.504
MIN error %FS	-0.362	-0.915	-0.610	-2.925	-3.318	-0.426
Absolute largest error %FS	0.545	1.249	0.610	2.925	4.785	0.504
Std. Devn. %FS	0.085	0.295	0.167	0.796	0.763	0.136
Average error %FS	0.000	0.000	-0.001	-0.002	0.000	0.000
Ratio of absolute largest error to Std. Devn.	6.39	4.23	3.65	3.67	6.27	3.72
# terms	36	26	30	20	15	31

Matrix "7" (Mod-B of "optimum")	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.487	1.357	0.610	2.424	5.175	0.531
MIN error %FS	-0.390	-1.033	-0.617	-2.816	-3.339	-0.437
Absolute largest error %FS	0.487	1.357	0.617	2.816	5.175	0.531
Std. Devn. %FS	0.086	0.295	0.180	0.801	0.763	0.142
Average error %FS	0.000	0.000	-0.001	-0.003	-0.001	0.000
Ratio of absolute largest error to Std. Devn.	5.64	4.61	3.43	3.52	6.78	3.73
# terms	36	28	26	22	17	27

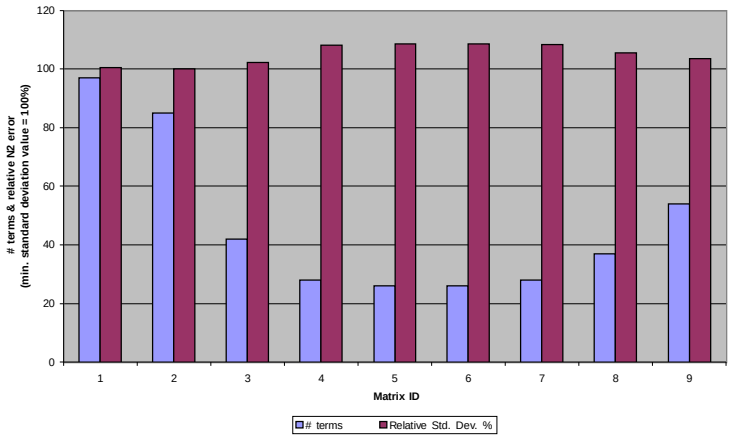
Matrix "8" (Mod-C of "optimum")	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.477	1.181	0.683	2.352	4.083	0.400
MIN error %FS	-0.423	-1.113	-0.700	-2.684	-3.441	-0.434
Absolute largest error %FS	0.477	1.181	0.700	2.684	4.083	0.434
Std. Devn. %FS	0.079	0.287	0.175	0.758	0.705	0.123
Average error %FS	0.000	0.000	-0.001	-0.003	-0.001	0.000
Ratio of absolute largest error to Std. Devn.	6.07	4.12	4.01	3.54	5.79	3.58
# terms	50	37	32	33	20	47

Matrix "9" (Mod-D of "optimum")	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.340	1.178	0.658	2.237	4.268	0.404
MIN error %FS	-0.422	-1.061	-0.697	-2.379	-3.373	-0.442
Absolute largest error %FS	0.422	1.178	0.697	2.379	4.268	0.442
Std. Devn. %FS	0.076	0.281	0.170	0.708	0.668	0.121
Average error %FS	0.000	0.000	0.000	-0.003	-0.001	0.000
Ratio of absolute largest error to Std. Devn.	5.59	4.19	4.11	3.36	6.39	3.66
# terms	60	54	50	54	60	63

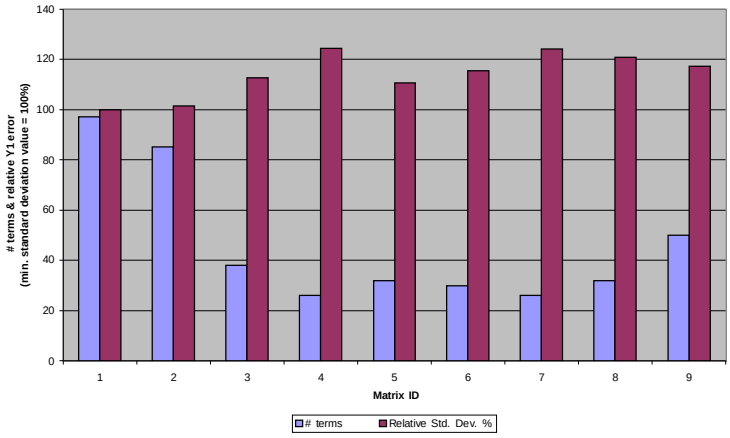
Mk.2A balance, N1 error relative standard deviations for Calibration Loads (File 07)



Mk.2A balance, N2 error relative standard deviations for Calibration Loads (File 07)



Mk.2A balance, Y1 error relative standard deviations for Calibration Loads (File 07)



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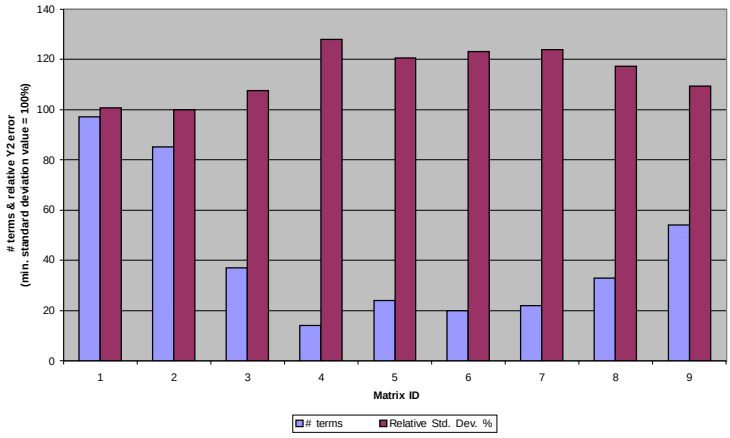
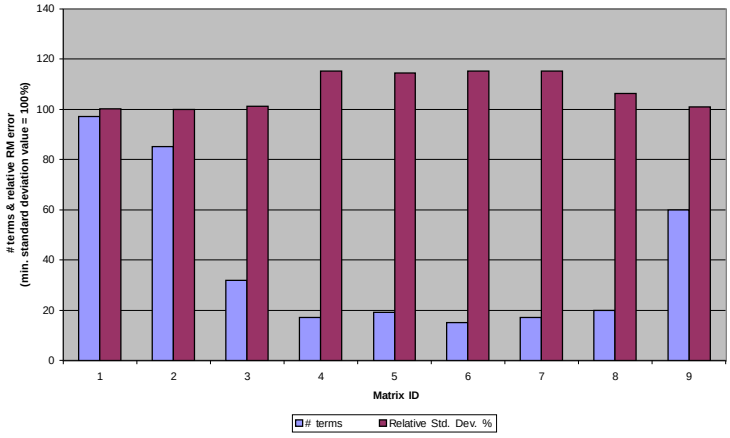


Mk.2A balance, RM error relative standard deviations for Calibration Loads (File 07)



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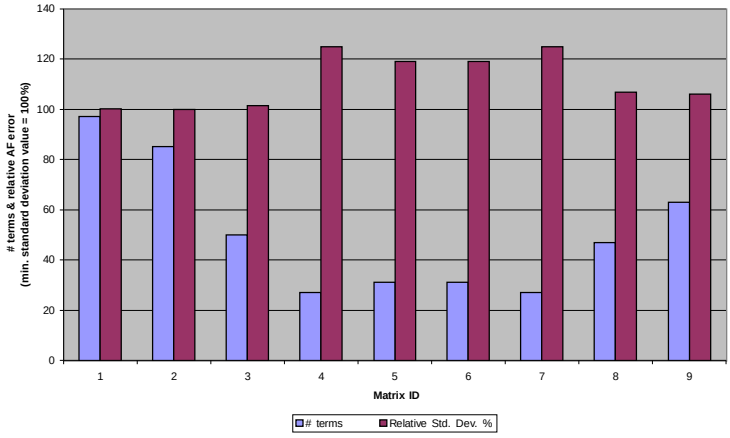

Matrix ID	
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7	Matrix with { 36, 28, 26, 22, 17, 27} terms/component, based on matrix "3" but modified as follows: a) for the F, |F|, F^2, F|F|, F^3 and |F^3|, set to zero all "absolute value" terms for which the corresponding "signed" term in "3" is zero, b) for the 2-load cross-product terms, set to zero the "absolute value" terms unless ALL 3 "absolute value" terms in "3" are non-zero, in which case INCLUDE ALL 4 cross-product terms, even if the "signed" cross-product term in "3" is zero.
8	Matrix with { 50, 37, 32, 33, 20, 47} terms/component, based on matrix "3" but modified as follows: a) for the F, |F|, F^2, F|F|, F^3 and |F^3|, set to zero all "absolute value" terms for which the corresponding "signed" term in "3" is zero, b) for the 2-load cross-product terms, set to zero the "absolute value" terms unless AT LEAST 2 "absolute value" terms in "3" are non-zero, in which case INCLUDE ALL 4 cross-product terms, even if the "signed" cross-product term in "3" is zero.
9	Matrix with { 60, 54, 50, 54, 60, 63} terms/component, based on matrix "3" but modified as follows: a) for the F, |F|, F^2, F|F|, F^3 and |F^3|, set to zero all "absolute value" terms for which the corresponding "signed" term in "3" is zero, b) for the 2-load cross-product terms, set to zero the "absolute value" terms unless AT LEAST 1 "absolute value" terms in "3" is non-zero, in which case INCLUDE ALL 4 cross-product terms, even if the "signed" cross-product term in "3" is zero.

Error statistics summary from loads calculation of the Mk.2A Manual Loads File 06 using different matrices.

Matrix "1" (6x97)	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.182	0.758	1.045	1.674	2.208	0.322
MIN error %FS	-0.284	-0.890	-0.287	-2.473	-2.603	-0.239
Absolute largest error %FS	0.284	0.890	1.045	2.473	2.603	0.322
Std. Devn. %FS	0.079	0.300	0.254	0.910	0.738	0.124
Average error %FS	-0.027	-0.203	0.188	0.172	-0.226	0.002
Ratio of absolute largest error to Std. Devn.	3.62	2.70	4.11	2.72	3.54	2.60
# terms	97	97	97	97	97	97

Matrix "2" (6x85)	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.177	0.807	1.023	1.086	1.843	0.359
MIN error %FS	-0.282	-0.741	-0.415	-2.663	-1.761	-0.215
Absolute largest error %FS	0.282	0.807	1.023	2.663	1.843	0.359
Std. Devn. %FS	0.073	0.306	0.247	0.855	0.612	0.117
Average error %FS	-0.012	0.012	0.144	-0.293	0.088	0.018
Ratio of absolute largest error to Std. Devn.	3.88	2.63	4.14	3.12	3.01	3.08
# terms	85	85	85	85	85	85

Matrix "3" (Norbert Ulbrich "optimum")	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.188	0.908	0.959	1.749	1.817	0.392
MIN error %FS	-0.260	-0.597	-0.367	-1.835	-2.010	-0.216
Absolute largest error %FS	0.260	0.908	0.959	1.835	2.010	0.392
Std. Devn. %FS	0.068	0.311	0.231	0.736	0.612	0.117
Average error %FS	-0.004	0.042	0.085	-0.046	0.062	0.023
Ratio of absolute largest error to Std. Devn.	3.80	2.92	4.14	2.49	3.28	3.34
# terms	52	42	38	37	32	50

Matrix "4" (Mod-A of "optimum")	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.205	0.828	0.969	2.151	1.399	0.315
MIN error %FS	-0.275	-0.733	-0.512	-1.983	-2.291	-0.301
Absolute largest error %FS	0.275	0.828	0.969	2.151	2.291	0.315
Std. Devn. %FS	0.062	0.304	0.242	0.810	0.632	0.109
Average error %FS	-0.007	0.017	0.068	-0.070	-0.043	-0.004
Ratio of absolute largest error to Std. Devn.	4.42	2.72	4.01	2.66	3.63	2.89
# terms	32	28	26	14	17	27

Matrix "5" (Mod-A2 of "optimum")	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.179	0.858	0.984	1.478	1.259	0.347
MIN error %FS	-0.271	-0.740	-0.483	-2.304	-2.185	-0.249
Absolute largest error %FS	0.271	0.858	0.984	2.304	2.185	0.347
Std. Devn. %FS	0.059	0.293	0.237	0.789	0.593	0.110
Average error %FS	-0.015	0.010	0.105	-0.174	-0.025	0.007
Ratio of absolute largest error to Std. Devn.	4.56	2.92	4.16	2.92	3.68	3.15
# terms	38	26	32	24	19	31

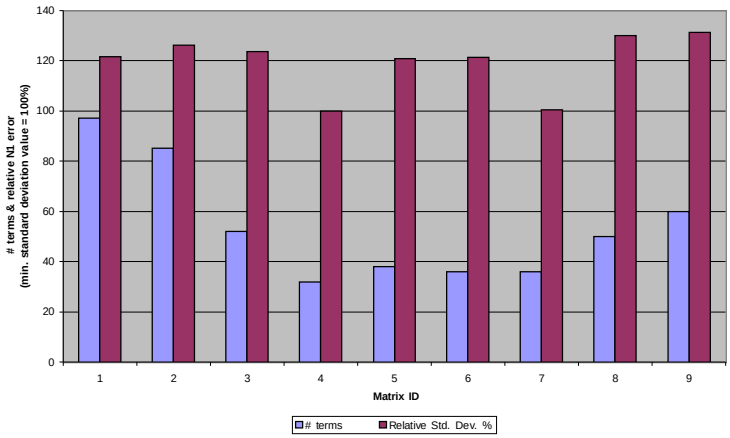
Matrix "6" (Mod-A3 of "optimum")	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.178	0.855	0.978	1.940	1.240	0.347
MIN error %FS	-0.270	-0.738	-0.502	-2.051	-2.219	-0.249
Absolute largest error %FS	0.270	0.855	0.978	2.051	2.219	0.347
Std. Devn. %FS	0.059	0.293	0.235	0.789	0.596	0.110
Average error %FS	-0.014	0.009	0.072	-0.056	-0.072	0.006
Ratio of absolute largest error to Std. Devn.	4.55	2.92	4.16	2.60	3.73	3.15
# terms	36	26	30	20	15	31

Matrix "7" (Mod-B of "optimum")	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.206	0.829	0.969	2.166	1.399	0.314
MIN error %FS	-0.285	-0.732	-0.532	-1.985	-2.291	-0.302
Absolute largest error %FS	0.285	0.829	0.969	2.166	2.291	0.314
Std. Devn. %FS	0.064	0.304	0.243	0.808	0.632	0.109
Average error %FS	-0.007	0.017	0.069	-0.054	-0.043	-0.004
Ratio of absolute largest error to Std. Devn.	4.45	2.72	3.98	2.68	3.63	2.88
# terms	36	28	26	22	17	27

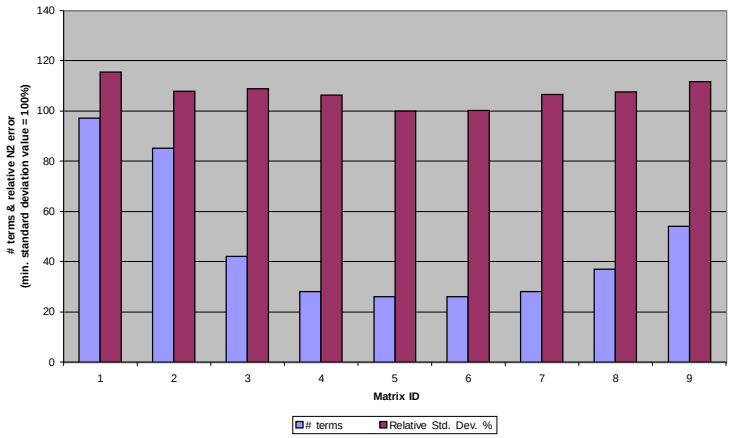
Matrix "8" (Mod-C of "optimum")	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.202	0.864	0.971	2.087	1.491	0.373
MIN error %FS	-0.282	-0.656	-0.362	-1.994	-2.080	-0.217
Absolute largest error %FS	0.282	0.864	0.971	2.087	2.080	0.373
Std. Devn. %FS	0.072	0.305	0.246	0.806	0.605	0.114
Average error %FS	-0.003	0.027	0.087	-0.066	-0.009	0.018
Ratio of absolute largest error to Std. Devn.	3.92	2.83	3.95	2.59	3.44	3.28
# terms	50	37	32	33	20	47

Matrix "9" (Mod-D of "optimum")	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.199	0.903	0.944	2.162	1.865	0.375
MIN error %FS	-0.285	-0.610	-0.351	-2.043	-2.020	-0.226
Absolute largest error %FS	0.285	0.903	0.944	2.162	2.020	0.375
Std. Devn. %FS	0.071	0.311	0.240	0.799	0.628	0.114
Average error %FS	-0.004	0.033	0.086	-0.076	0.062	0.019
Ratio of absolute largest error to Std. Devn.	4.01	2.90	3.93	2.71	3.22	3.28
# terms	60	54	50	54	60	63

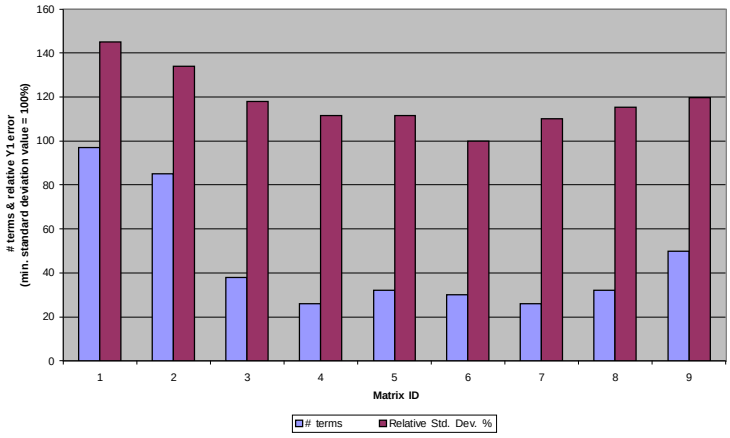
Mk.2A balance, N1 error relative standard deviations for Manual Loads (File 06)



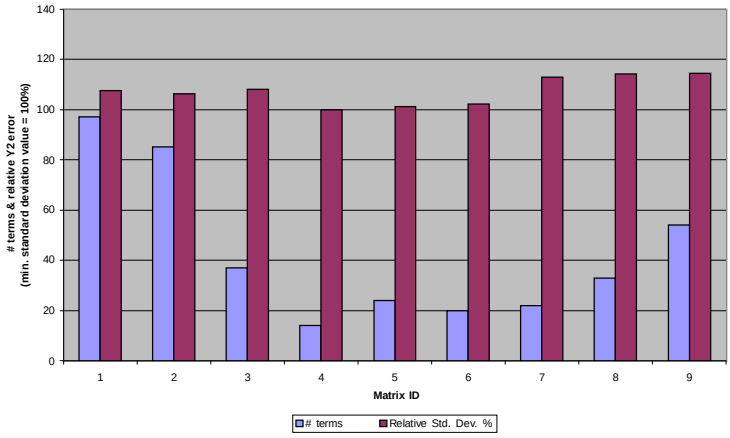
Mk.2A balance, N2 error relative standard deviations for Manual Loads (File 06)



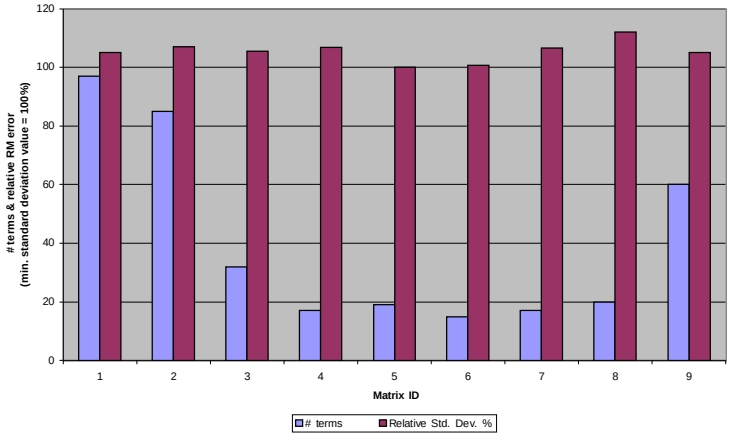
Mk.2A balance, Y1 error relative standard deviations for Manual Loads (File 06)



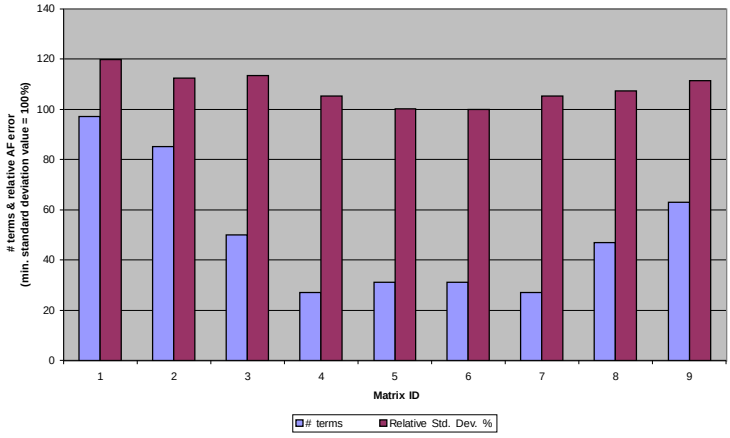
Mk.2A balance, Y2 error relative standard deviations for Manual Loads (File 06)



Mk.2A balance, RM error relative standard deviations for Manual Loads (File 06)



Mk.2A balance, AF error relative standard deviations for Manual Loads (File 06)



Matrix ID	
1	Full 6 x 97 math model as in AIAA R-091-2003
2	6 x 85 math model = matrix "1" with the load cubed, (F^3 and $|F^3|$), terms excluded (set to zero)
3	Norbert Ulbrich's "optimum" matrix from BALFIT's automatic term selection algorithm, terms/component = {52, 42, 38, 37, 32, 50}
4	Matrix with { 32, 28, 26, 14, 17, 27} terms/component, based on matrix "3" but modified as follows: a) for the F, |F|, F^2, F.|F|, F^3 and |F^3|, set to zero all "absolute value" terms for which the corresponding "signed" term in "3" is zero, b) for the 2-load cross-product terms, set to zero all "absolute value" terms for which the corresponding "signed" product term in "3" is zero, c) for the 2-load cross-product terms, if the "signed" product term in "3" is non-zero then set to zero all "absolute value" terms if any of those 3 terms is zero.
5	Matrix with { 38, 26, 32, 24, 19, 31} terms/component, based on matrix "3" but modified as follows: a) for the F and |F| terms, INCLUDE those terms for which both the "signed" and "absolute value" terms in "3" are zero, b) for the F^2 and F.|F| terms, INCLUDE any "signed" terms that are zero in "3", but for which the "absolute value" terms are non-zero, c) for the F^3 and |F^3|, zero ALL terms, d) for the 2-load cross-product terms, set to zero all "absolute value" terms for which the corresponding "signed" product term in "3" is zero, e) for the 2-load cross-product terms, if the "signed" product term in "3" is non-zero then set to zero all "absolute value" terms if any of those 3 terms is zero.
6	Matrix with { 36, 26, 30, 20, 15, 31} terms/component, based on matrix "3" but modified as follows: a) for the F^2 and F.|F| terms, INCLUDE any "signed" terms that are zero in "3", but for which the "absolute value" terms are non-zero, b) for the F^3 and |F^3|, zero ALL terms, c) for the 2-load cross-product terms, set to zero all "absolute value" terms for which the corresponding "signed" product term in "3" is zero, d) for the 2-load cross-product terms, if the "signed" product term in "3" is non-zero then set to zero all "absolute value" terms if any of those 3 terms is zero.
7	Matrix with { 36, 28, 26, 22, 17, 27} terms/component, based on matrix "3" but modified as follows: a) for the F, |F|, F^2, F.|F|, F^3 and |F^3|, set to zero all "absolute value" terms for which the corresponding "signed" term in "3" is zero, b) for the 2-load cross-product terms, set to zero the "absolute value" terms unless ALL 3 "absolute value" terms in "3" are non-zero, in which case INCLUDE ALL 4 cross-product terms, even if the "signed" cross-product term in "3" is zero.
8	Matrix with { 50, 37, 32, 33, 20, 47} terms/component, based on matrix "3" but modified as follows: a) for the F, |F|, F^2, F.|F|, F^3 and |F^3|, set to zero all "absolute value" terms for which the corresponding "signed" term in "3" is zero, b) for the 2-load cross-product terms, set to zero the "absolute value" terms unless AT LEAST 2 "absolute value" terms in "3" are non-zero, in which case INCLUDE ALL 4 cross-product terms, even if the "signed" cross-product term in "3" is zero.
9	Matrix with { 60, 54, 50, 54, 60, 63} terms/component, based on matrix "3" but modified as follows: a) for the F, |F|, F^2, F.|F|, F^3 and |F^3|, set to zero all "absolute value" terms for which the corresponding "signed" term in "3" is zero, b) for the 2-load cross-product terms, set to zero the "absolute value" terms unless AT LEAST 1 "absolute value" terms in "3" is non-zero, in which case INCLUDE ALL 4 cross-product terms, even if the "signed" cross-product term in "3" is zero.

Error statistics summary from loads calculation of the Mk.2A generic 6-component W/T Test Loads File 03 using different matrices.

Matrix "1" (6x97)	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.022	0.913	0.969	2.228	2.867	0.317
MIN error %FS	-0.478	-1.161	-0.192	-3.821	-2.998	-0.412
Absolute largest error %FS	0.478	1.161	0.969	3.821	2.998	0.412
Std. Deven. %FS	0.104	0.467	0.226	1.110	1.209	0.167
Average error %FS	-0.256	-0.127	0.191	-0.571	-0.245	-0.051
Ratio of absolute largest error to Std. Devn.	4.60	2.48	4.28	3.44	2.49	2.46
# terms	97	97	97	97	97	97

Matrix "2" (6x85)	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.088	0.636	0.849	2.411	2.435	0.220
MIN error %FS	-0.477	-1.086	-0.291	-3.427	-3.280	-0.418
Absolute largest error %FS	0.477	1.086	0.849	3.427	3.280	0.418
Std. Deven. %FS	0.108	0.427	0.209	1.097	1.229	0.157
Average error %FS	-0.233	-0.262	0.099	-0.360	-0.760	-0.081
Ratio of absolute largest error to Std. Devn.	4.43	2.49	4.07	3.12	2.67	2.67
# terms	85	85	85	85	85	85

Matrix "3" (Norbert Ulbrich "optimum")	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.099	0.673	0.512	2.989	2.384	0.229
MIN error %FS	-0.450	-1.062	-0.570	-2.176	-3.290	-0.415
Absolute largest error %FS	0.450	1.062	0.570	2.989	3.290	0.415
Std. Deven. %FS	0.106	0.441	0.184	1.114	1.218	0.158
Average error %FS	-0.218	-0.260	-0.075	0.506	-0.763	-0.075
Ratio of absolute largest error to Std. Devn.	4.26	2.41	3.10	2.69	2.72	2.62
# terms	52	42	38	37	32	50

Matrix "4" (Mod-A of "optimum")	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.148	0.633	0.284	2.669	2.363	0.180
MIN error %FS	-0.365	-1.102	-0.742	-2.240	-3.427	-0.484
Absolute largest error %FS	0.365	1.102	0.742	2.669	3.427	0.484
Std. Deven. %FS	0.085	0.431	0.174	1.032	1.226	0.147
Average error %FS	-0.203	-0.279	-0.188	0.410	-0.966	-0.176
Ratio of absolute largest error to Std. Devn.	4.27	2.55	4.27	2.59	2.80	3.30
# terms	32	28	26	14	17	27

Matrix "5" (Mod-A2 of "optimum")	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.073	0.562	0.594	2.431	1.878	0.229
MIN error %FS	-0.432	-1.103	-0.380	-2.573	-3.466	-0.398
Absolute largest error %FS	0.432	1.103	0.594	2.573	3.466	0.398
Std. Deven. %FS	0.103	0.405	0.174	1.043	1.148	0.140
Average error %FS	-0.242	-0.305	-0.003	0.148	-1.108	-0.107
Ratio of absolute largest error to Std. Devn.	4.18	2.72	3.42	2.47	3.02	2.85
# terms	38	26	32	24	19	31

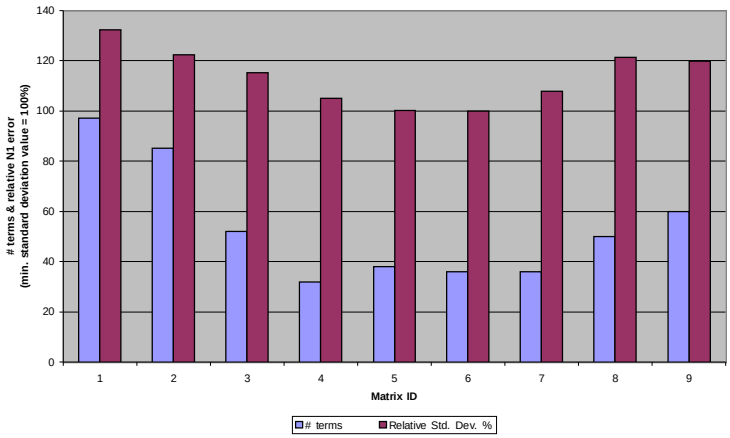
Matrix "6" (Mod-A3 of "optimum")	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.073	0.562	0.337	2.855	1.733	0.228
MIN error %FS	-0.431	-1.104	-0.567	-1.972	-3.610	-0.399
Absolute largest error %FS	0.431	1.104	0.567	2.855	3.610	0.399
Std. Deven. %FS	0.104	0.406	0.156	1.053	1.156	0.139
Average error %FS	-0.240	-0.305	-0.113	0.568	-1.225	-0.108
Ratio of absolute largest error to Std. Devn.	4.16	2.72	3.64	2.71	3.12	2.86
# terms	36	26	30	20	15	31

Matrix "7" (Mod-B of "optimum")	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.135	0.635	0.297	2.602	2.359	0.180
MIN error %FS	-0.371	-1.102	-0.738	-2.456	-3.429	-0.484
Absolute largest error %FS	0.371	1.102	0.738	2.602	3.429	0.484
Std. Deven. %FS	0.086	0.432	0.171	1.165	1.225	0.147
Average error %FS	-0.207	-0.278	-0.187	0.435	-0.967	-0.176
Ratio of absolute largest error to Std. Devn.	4.33	2.55	4.31	2.23	2.80	3.29
# terms	36	28	26	22	17	27

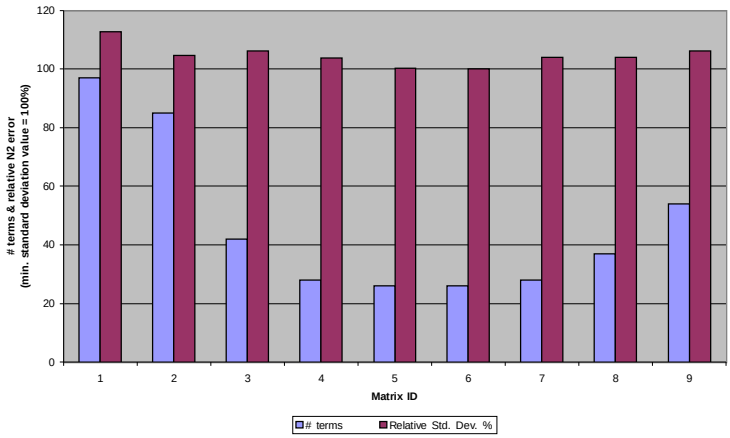
Matrix "8" (Mod-C of "optimum")	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.129	0.676	0.370	3.080	2.462	0.248
MIN error %FS	-0.468	-1.075	-0.689	-2.529	-3.605	-0.417
Absolute largest error %FS	0.468	1.075	0.689	3.080	3.605	0.417
Std. Deven. %FS	0.111	0.436	0.180	1.178	1.286	0.150
Average error %FS	-0.221	-0.246	-0.135	0.524	-1.021	-0.107
Ratio of absolute largest error to Std. Devn.	4.21	2.47	3.84	2.61	2.80	2.79
# terms	50	37	32	33	20	47

Matrix "9" (Mod-D of "optimum")	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.131	0.708	0.441	2.932	2.196	0.230
MIN error %FS	-0.473	-1.062	-0.687	-2.588	-3.299	-0.422
Absolute largest error %FS	0.473	1.062	0.687	2.932	3.299	0.422
Std. Deven. %FS	0.112	0.463	0.186	1.181	1.207	0.153
Average error %FS	-0.221	-0.251	-0.112	0.465	-0.966	-0.115
Ratio of absolute largest error to Std. Devn.	4.22	2.35	3.68	2.48	2.73	2.72
# terms	60	54	50	54	60	63

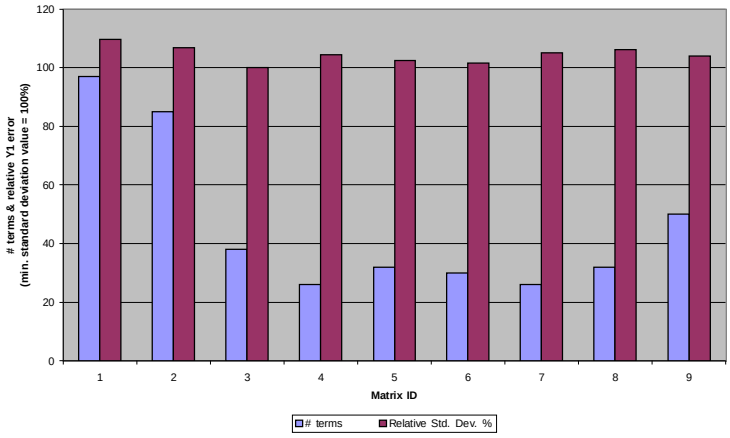
Mk.2A balance, N1 error relative standard deviations for 6-component generic W/T Test Loads (File 03)



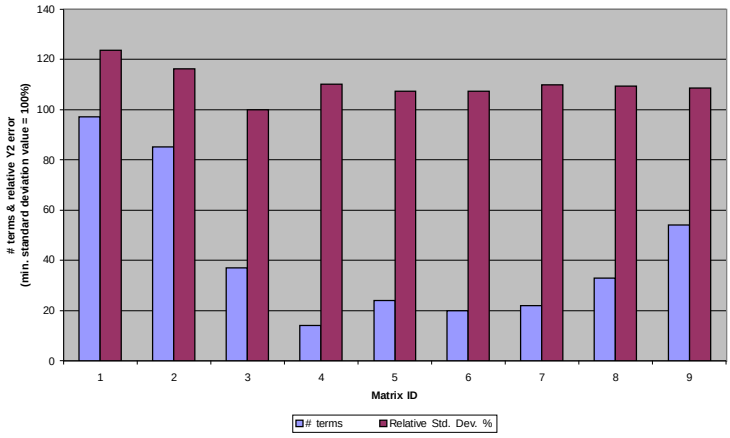
Mk.2A balance, N2 error relative standard deviations for 6-component generic W/T Test Loads (File 03)



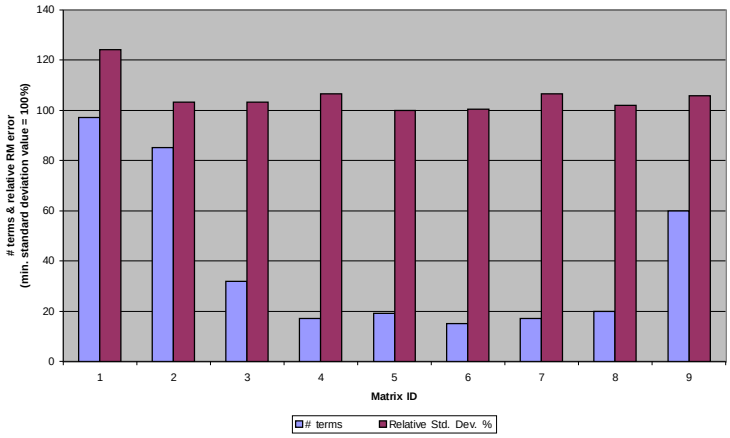
Mk.2A balance, Y1 error relative standard deviations for 6-component generic W/T Test Loads (File 03)



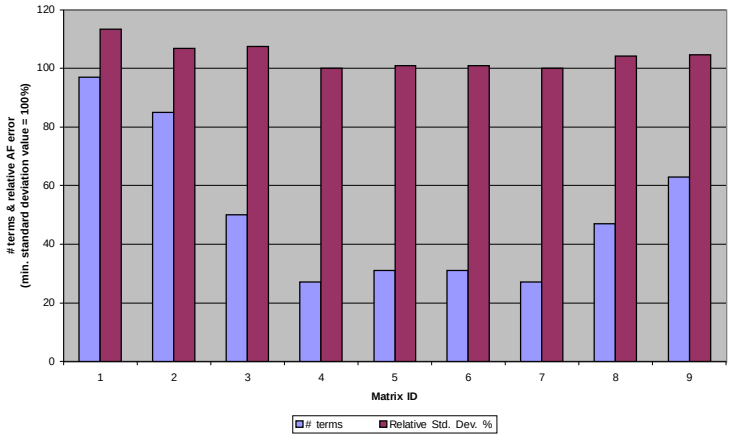
Mk.2A balance, Y2 error relative standard deviations for 6-component generic W/T Test Loads (File 03)



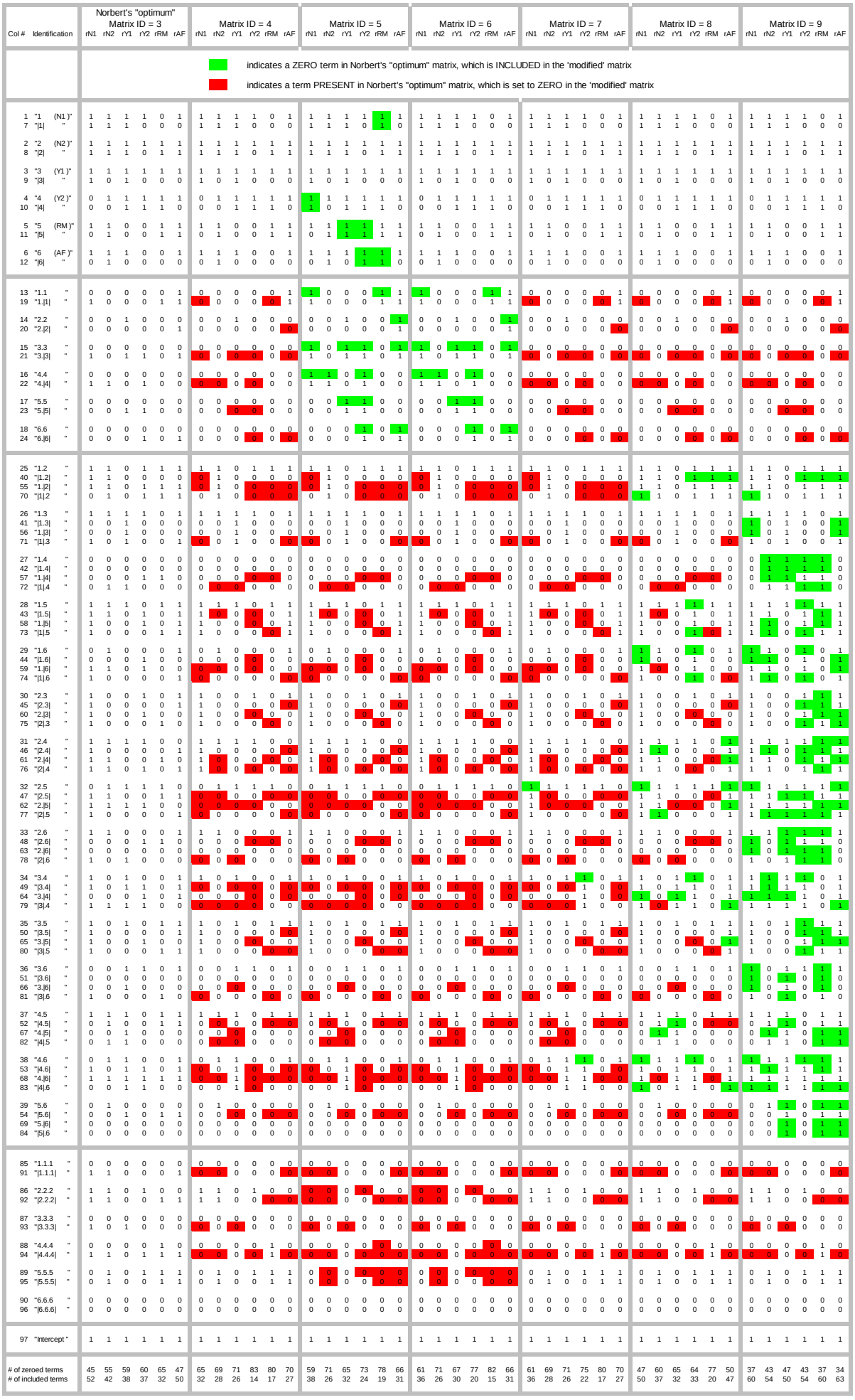
Mk.2A balance, RM error relative standard deviations for 6-component generic W/T Test Loads (File 03)



Mk.2A balance, AF error relative standard deviations for 6-component generic W/T Test Loads (File 03)



Matrix ID	
1	Full 6 x 97 math model as in AIAA R-091-2003
2	6 x 85 math model = matrix “1” with the load cubed, (F^3 and $\|F^3\|$), terms excluded (set to zero)
3	Norbert Ulbrich’s “optimum” matrix from BALFIT’s automatic term selection algorithm, terms/component = {52, 42, 38, 37, 32, 50}
4	Matrix with { 32, 28, 26, 14, 17, 27} terms/component, based on matrix “3” but modified as follows: a) for the F, |F|, F^2, F.|F|, F^3 and |F^3|, set to zero all "absolute value" terms for which the corresponding "signed" term in “3” is zero, b) for the 2-load cross-product terms, set to zero all "absolute value" terms for which the corresponding "signed" product term in “3” is zero, c) for the 2-load cross-product terms, if the "signed" product term in “3” is non-zero then set to zero all "absolute value" terms if any of those 3 terms is zero.
5	Matrix with { 38, 26, 32, 24, 19, 31} terms/component, based on matrix “3” but modified as follows: a) for the F and |F| terms, INCLUDE those terms for which both the "signed" and "absolute value" terms in “3” are zero, b) for the F^2 and F.|F| terms, INCLUDE any "signed" terms that are zero in “3”, but for which the "absolute value" terms are non-zero, c) for the F^3 and |F^3|, zero ALL terms, d) for the 2-load cross-product terms, set to zero all "absolute value" terms for which the corresponding "signed" product term in “3” is zero, e) for the 2-load cross-product terms, if the "signed" product term in “3” is non-zero then set to zero all "absolute value" terms if any of those 3 terms is zero.
6	Matrix with { 36, 26, 30, 20, 15, 31} terms/component, based on matrix “3” but modified as follows: a) for the F^2 and F.|F| terms, INCLUDE any "signed" terms that are zero in “3”, but for which the "absolute value" terms are non-zero, b) for the F^3 and |F^3|, zero ALL terms, c) for the 2-load cross-product terms, set to zero all "absolute value" terms for which the corresponding "signed" product term in “3” is zero, d) for the 2-load cross-product terms, if the "signed" product term in “3” is non-zero then set to zero all "absolute value" terms if any of those 3 terms is zero.
7	Matrix with { 36, 28, 26, 22, 17, 27} terms/component, based on matrix “3” but modified as follows: a) for the F, |F|, F^2, F.|F|, F^3 and |F^3|, set to zero all "absolute value" terms for which the corresponding "signed" term in “3” is zero, b) for the 2-load cross-product terms, set to zero the "absolute value" terms unless ALL 3 "absolute value" terms in “3” are non-zero, in which case INCLUDE ALL 4 cross-product terms, even if the "signed" cross-product term in “3” is zero.
8	Matrix with { 50, 37, 32, 33, 20, 47} terms/component, based on matrix “3” but modified as follows: a) for the F, |F|, F^2, F.|F|, F^3 and |F^3|, set to zero all "absolute value" terms for which the corresponding "signed" term in “3” is zero, b) for the 2-load cross-product terms, set to zero the "absolute value" terms unless AT LEAST 2 "absolute value" terms in “3” are non-zero, in which case INCLUDE ALL 4 cross-product terms, even if the "signed" cross-product term in “3” is zero.
9	Matrix with { 60, 54, 50, 54, 60, 63} terms/component, based on matrix “3” but modified as follows: a) for the F, |F|, F^2, F.|F|, F^3 and |F^3|, set to zero all "absolute value" terms for which the corresponding "signed" term in “3” is zero, b) for the 2-load cross-product terms, set to zero the "absolute value" terms unless AT LEAST 1 "absolute value" terms in “3” is non-zero, in which case INCLUDE ALL 4 cross-product terms, even if the "signed" cross-product term in “3” is zero.


Norbert's "optimum"
Matrix ID = 3
Matrix ID = 4
Matrix ID = 5
Matrix ID = 6
Matrix ID = 7
Matrix ID = 8
Matrix ID = 9
Col # Identification
rN1 rN2 rY1 rY2 rRM rAF
indicates a ZERO term in Norbert's "optimum" matrix, which is INCLUDED in the 'modified' matrix
indicates a term PRESENT in Norbert's "optimum" matrix, which is set to ZERO in the 'modified' matrix
1 "1 (N1)"
7 "|1| "
2 "2 (N2)"
8 "|2| "
3 "3 (Y1)"
9 "|3| "
4 "4 (Y2)"
10 "|4| "
5 "5 (RM)"
11 "|5| "
6 "6 (AF)"
12 "|6| "
13 "1.1 "
19 "1.|1| "
14 "2.2 "
20 "2.|2| "
15 "3.3 "
21 "3.|3| "
16 "4.4 "
22 "4.|4| "
17 "5.5 "
23 "5.|5| "
18 "6.6 "
24 "6.|6| "
25 "1.2 "
40 "|1.2| "
55 "1.|2| "
70 "|1.|2 "
26 "1.3 "
41 "|1.3| "
56 "1.|3| "
71 "|1.|3 "
27 "1.4 "
42 "|1.4| "
57 "1.|4| "
72 "|1.|4 "
28 "1.5 "
43 "|1.5| "
58 "1.|5| "
73 "|1.|5 "
29 "1.6 "
44 "|1.6| "
59 "1.|6| "
74 "|1.|6 "
30 "2.3 "
45 "|2.3| "
60 "2.|3| "
75 "|2|.3 "
31 "2.4 "
46 "|2.4| "
61 "2.|4| "
76 "|2|.4 "
32 "2.5 "
47 "|2.5| "
62 "2.|5| "
77 "|2|.5 "
33 "2.6 "
48 "|2.6| "
63 "2.|6| "
78 "|2|.6 "
34 "3.4 "
49 "|3.4| "
64 "3.|4| "
79 "|3|.4 "
35 "3.5 "
50 "|3.5| "
65 "3.|5| "
80 "|3|.5 "
36 "3.6 "
51 "|3.6| "
66 "3.|6| "
81 "|3|.6 "
37 "4.5 "
52 "|4.5| "
67 "4.|5| "
82 "|4|.5 "
38 "4.6 "
53 "|4.6| "
68 "4.|6| "
83 "|4|.6 "
39 "5.6 "
54 "|5.6| "
69 "5.|6| "
84 "|5|.6 "
85 "1.1.1 "
91 "|1.1.1| "
86 "2.2.2 "
92 "|2.2.2| "
87 "3.3.3 "
93 "|3.3.3| "
88 "4.4.4 "
94 "|4.4.4| "
89 "5.5.5 "
95 "|5.5.5| "
90 "6.6.6 "
96 "|6.6.6| "
97 "Intercept "
# of zeroed terms
# of included terms
45 55 59 60 65 47
52 42 38 37 32 50
65 69 71 83 80 70
32 28 26 14 17 27
59 71 65 73 78 66
38 26 32 24 19 31
61 71 67 77 82 66
36 26 30 20 15 31
61 69 71 75 80 70
36 28 26 22 17 27
47 60 65 64 77 50
50 37 32 33 20 47
37 43 47 50 43 37 34
60 54 50 54 60 63

Error statistics summary from loads calculation of the Mk.2A Calibration Loads File 07 using different matrices.

Matrix "1" (6x97)	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.362	1.238	0.584	2.282	4.056	0.379
MIN error %FS	-0.472	-0.999	-0.770	-2.517	-3.023	-0.384
Absolute largest error %FS	0.472	1.238	0.770	2.517	4.056	0.384
Std. Devn. %FS	0.066	0.274	0.145	0.651	0.663	0.114
Average error %FS	0.000	0.000	0.000	-0.003	0.000	0.000
Ratio of absolute largest error to Std. Devn.	7.13	4.52	5.32	3.86	6.11	3.36
# terms	97	97	97	97	97	97

Matrix "2" (6x85)	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.430	1.153	0.597	2.186	4.217	0.371
MIN error %FS	-0.437	-0.982	-0.752	-2.340	-3.240	-0.379
Absolute largest error %FS	0.437	1.153	0.752	2.340	4.217	0.379
Std. Devn. %FS	0.070	0.272	0.147	0.647	0.662	0.114
Average error %FS	0.000	0.000	0.000	-0.002	-0.001	0.000
Ratio of absolute largest error to Std. Devn.	6.28	4.24	5.12	3.62	6.37	3.32
# terms	85	85	85	85	85	85

Matrix "3" (Norbert Ulbrich "optimum")	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.404	1.207	0.521	2.196	4.222	0.376
MIN error %FS	-0.414	-1.058	-0.713	-2.351	-3.384	-0.404
Absolute largest error %FS	0.414	1.207	0.713	2.351	4.222	0.404
Std. Devn. %FS	0.073	0.278	0.163	0.696	0.671	0.116
Average error %FS	0.000	0.000	-0.001	-0.003	-0.001	0.000
Ratio of absolute largest error to Std. Devn.	5.69	4.34	4.37	3.38	6.29	3.49
# terms	52	42	38	37	32	50

Matrix "4" (Mod-A of "optimum")	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.481	1.355	0.593	2.514	5.175	0.531
MIN error %FS	-0.390	-1.032	-0.623	-2.995	-3.325	-0.437
Absolute largest error %FS	0.481	1.355	0.623	2.995	5.175	0.531
Std. Devn. %FS	0.087	0.295	0.180	0.827	0.763	0.142
Average error %FS	0.000	0.000	-0.001	-0.003	0.000	0.000
Ratio of absolute largest error to Std. Devn.	5.54	4.60	3.46	3.62	6.78	3.73
# terms	32	28	26	14	17	27

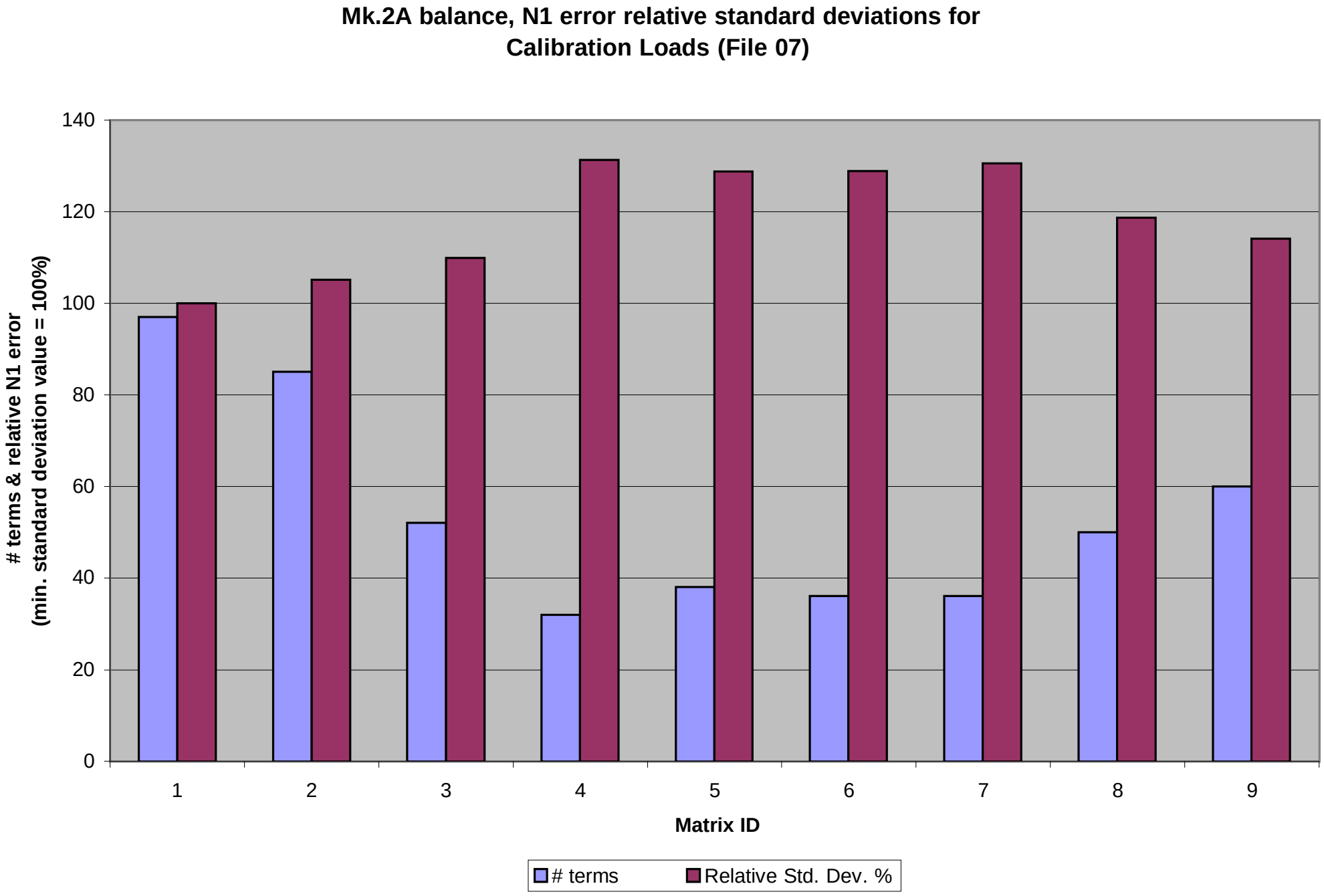
Matrix "5" (Mod-A2 of "optimum")	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.543	1.251	0.581	2.256	4.703	0.504
MIN error %FS	-0.362	-0.915	-0.634	-2.715	-3.312	-0.426
Absolute largest error %FS	0.543	1.251	0.634	2.715	4.703	0.504
Std. Devn. %FS	0.085	0.295	0.160	0.779	0.758	0.136
Average error %FS	0.000	0.000	-0.001	-0.004	0.000	0.000
Ratio of absolute largest error to Std. Devn.	6.37	4.24	3.96	3.48	6.20	3.72
# terms	38	26	32	24	19	31

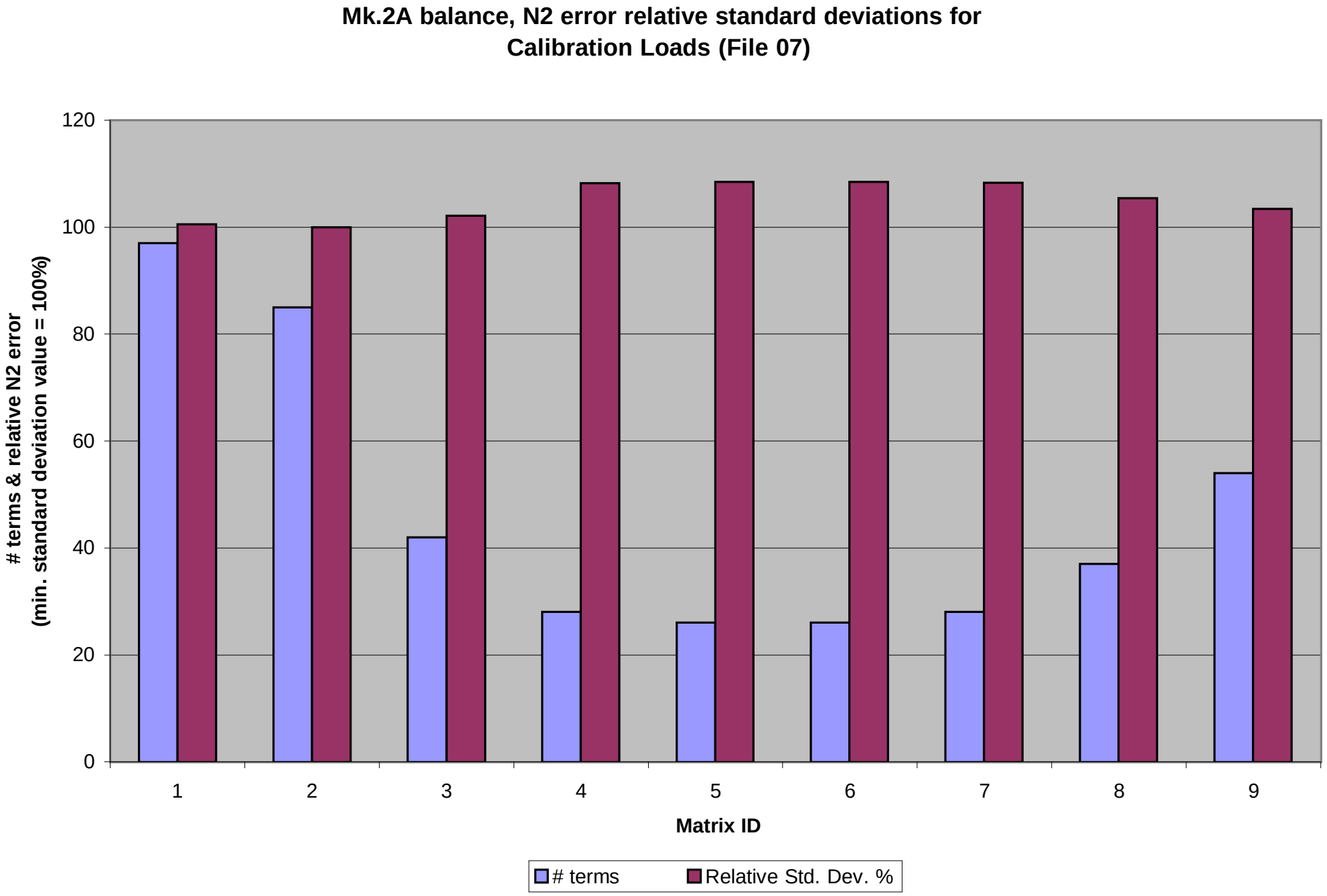
Matrix "6" (Mod-A3 of "optimum")	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.545	1.249	0.584	2.195	4.785	0.504
MIN error %FS	-0.362	-0.915	-0.610	-2.925	-3.318	-0.426
Absolute largest error %FS	0.545	1.249	0.610	2.925	4.785	0.504
Std. Devn. %FS	0.085	0.295	0.167	0.796	0.763	0.136
Average error %FS	0.000	0.000	-0.001	-0.002	0.000	0.000
Ratio of absolute largest error to Std. Devn.	6.39	4.23	3.65	3.67	6.27	3.72
# terms	36	26	30	20	15	31

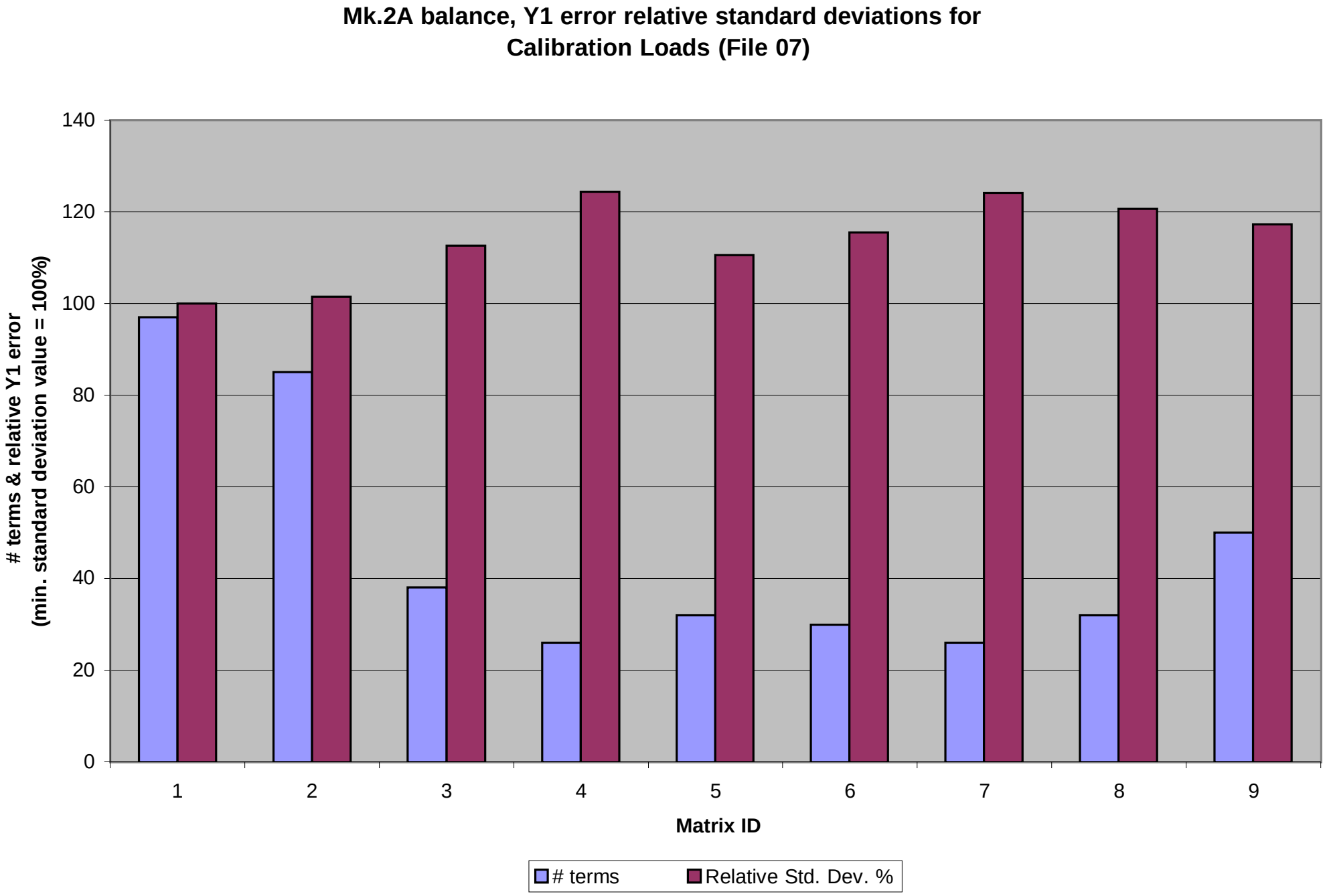
Matrix "7" (Mod-B of "optimum")	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.487	1.357	0.610	2.424	5.175	0.531
MIN error %FS	-0.390	-1.033	-0.617	-2.816	-3.330	-0.437
Absolute largest error %FS	0.487	1.357	0.617	2.816	5.175	0.531
Std. Devn. %FS	0.086	0.295	0.180	0.801	0.763	0.142
Average error %FS	0.000	0.000	-0.001	-0.003	-0.001	0.000
Ratio of absolute largest error to Std. Devn.	5.64	4.61	3.43	3.52	6.78	3.73
# terms	36	28	26	22	17	27

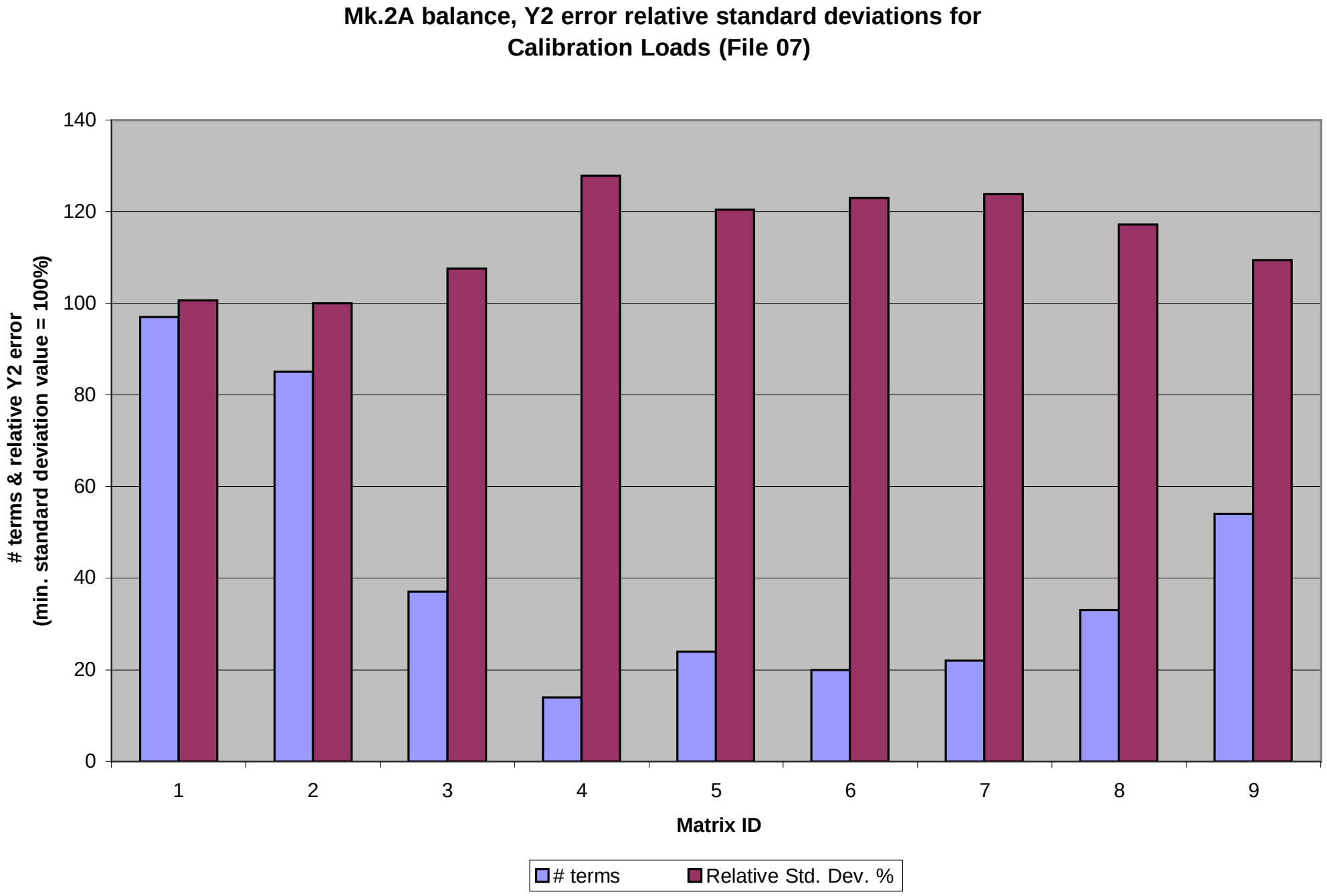
Matrix "8" (Mod-C of "optimum")	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.477	1.181	0.683	2.352	4.083	0.400
MIN error %FS	-0.423	-1.113	-0.700	-2.684	-3.441	-0.434
Absolute largest error %FS	0.477	1.181	0.700	2.684	4.083	0.434
Std. Devn. %FS	0.079	0.287	0.175	0.758	0.705	0.122
Average error %FS	0.000	0.000	-0.001	-0.003	-0.001	0.000
Ratio of absolute largest error to Std. Devn.	6.07	4.12	4.01	3.54	5.79	3.56
# terms	50	37	32	33	20	47

Matrix "9" (Mod-D of "optimum")	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.340	1.178	0.658	2.237	4.268	0.404
MIN error %FS	-0.422	-1.061	-0.697	-2.379	-3.373	-0.442
Absolute largest error %FS	0.422	1.178	0.697	2.379	4.268	0.442
Std. Devn. %FS	0.076	0.281	0.170	0.708	0.668	0.121
Average error %FS	0.000	0.000	0.000	-0.003	-0.001	0.000
Ratio of absolute largest error to Std. Devn.	5.59	4.19	4.11	3.36	6.39	3.66
# terms	60	54	50	54	60	63


Mk.2A balance, N1 error relative standard deviations for Calibration Loads (File 07)
terms & relative N1 error (min. standard deviation value = 100%)
140
120
100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
Matrix ID
terms
Relative Std. Dev. %


Mk.2A balance, N2 error relative standard deviations for Calibration Loads (File 07)
terms & relative N2 error (min. standard deviation value = 100%)
120
100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
Matrix ID
terms
Relative Std. Dev. %


Mk.2A balance, Y1 error relative standard deviations for Calibration Loads (File 07)
terms & relative Y1 error (min. standard deviation value = 100%)
140
120
100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
Matrix ID
terms
Relative Std. Dev. %


Mk.2A balance, Y2 error relative standard deviations for Calibration Loads (File 07)
terms & relative Y2 error (min. standard deviation value = 100%)
140
120
100
80
60
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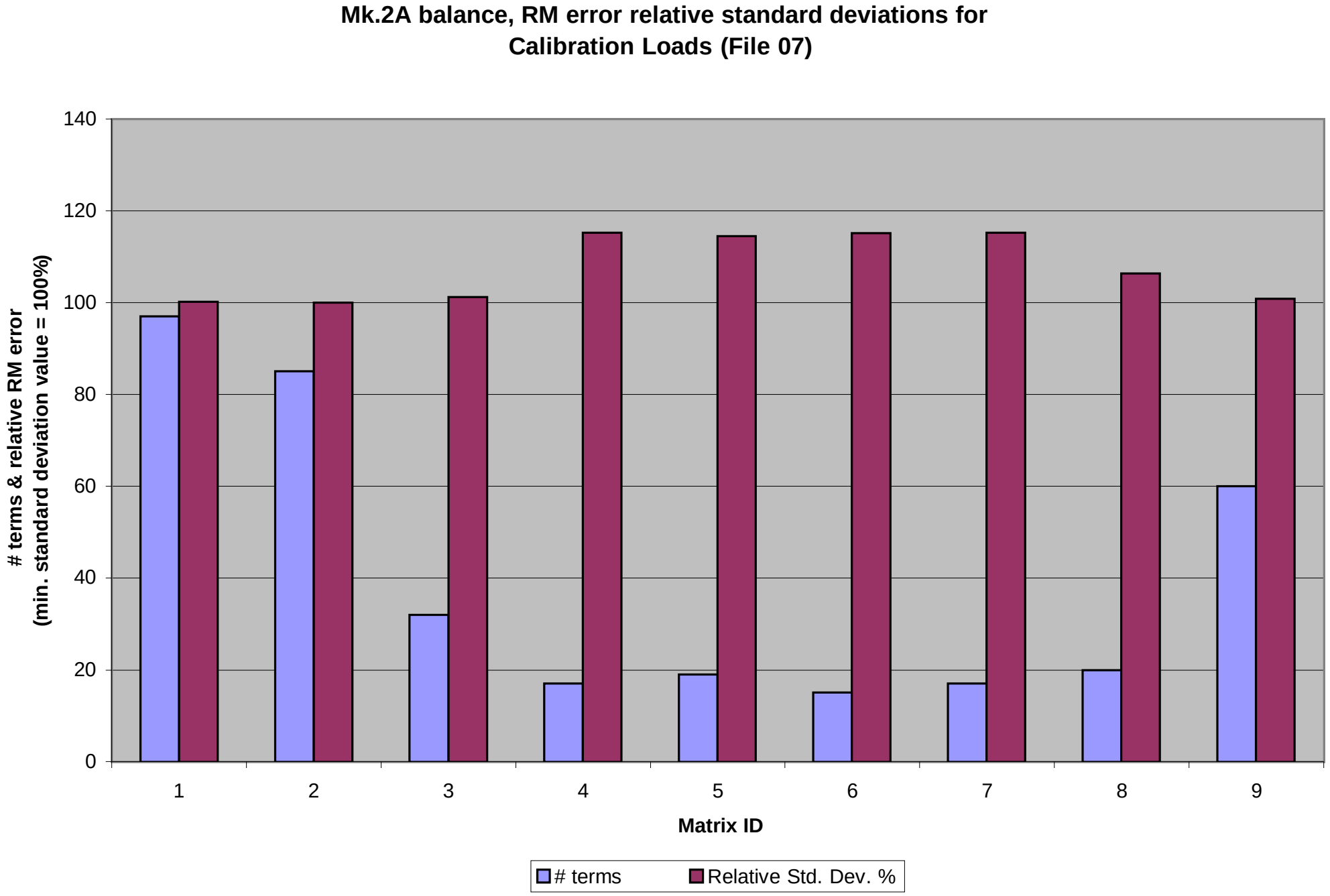
20
0
1
2
3
4
5
6
7
8
9
Matrix ID
terms
Relative Std. Dev. %


Mk.2A balance, RM error relative standard deviations for Calibration Loads (File 07)
terms & relative RM error (min. standard deviation value = 100%)
140
120
100
80
60
40
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1
2
3
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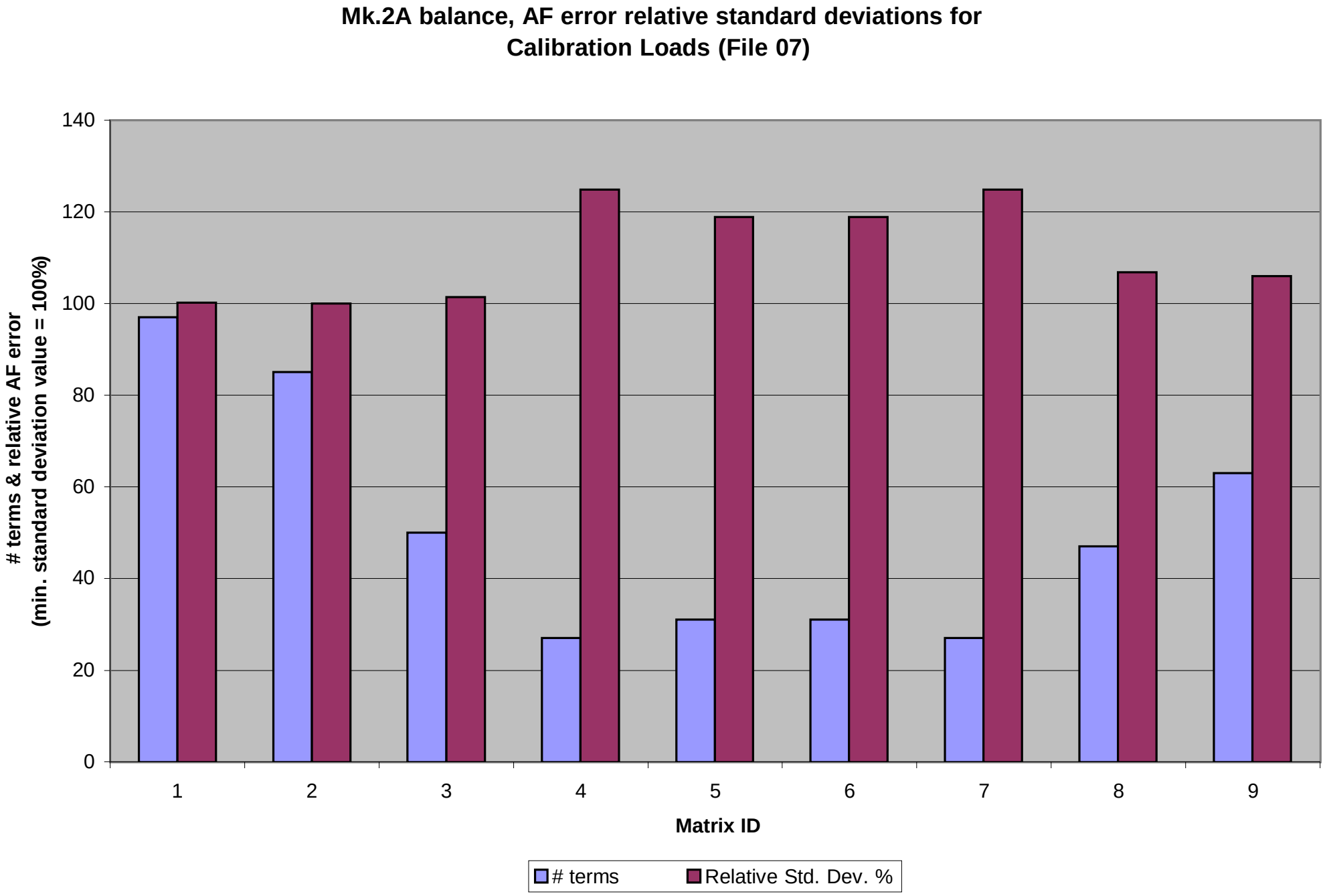
5
6
7
8
9
Matrix ID
terms
Relative Std. Dev. %


Mk.2A balance, AF error relative standard deviations for Calibration Loads (File 07)
terms & relative AF error (min. standard deviation value = 100%)
140
120
100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
Matrix ID
terms
Relative Std. Dev. %

Error statistics summary from loads calculation of the Mk.2A Manual Loads File 06 using different matrices.

Matrix "1" (6x97)	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.182	0.756	1.045	1.674	2.208	0.322
MIN error %FS	-0.284	-0.890	-0.287	-2.473	-2.603	-0.239
Absolute largest error %FS	0.284	0.890	1.045	2.473	2.603	0.322
Std. Devn. %FS	0.079	0.330	0.254	0.910	0.736	0.124
Average error %FS	-0.027	-0.203	0.188	0.172	-0.226	0.002
Ratio of absolute largest error to Std. Devn.	3.62	2.70	4.11	2.72	3.54	2.60
# terms	97	97	97	97	97	97

Matrix "2" (6x85)	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.177	0.807	1.023	1.086	1.843	0.359
MIN error %FS	-0.282	-0.741	-0.415	-2.663	-1.761	-0.215
Absolute largest error %FS	0.282	0.807	1.023	2.663	1.843	0.359
Std. Devn. %FS	0.073	0.306	0.247	0.855	0.612	0.117
Average error %FS	-0.012	0.012	0.144	-0.293	0.088	0.018
Ratio of absolute largest error to Std. Devn.	3.88	2.63	4.14	3.12	3.01	3.08
# terms	85	85	85	85	85	85

Matrix "3" (Norbert Ulbrich "optimum")	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.188	0.908	0.959	1.749	1.817	0.392
MIN error %FS	-0.260	-0.597	-0.367	-1.835	-2.010	-0.216
Absolute largest error %FS	0.260	0.908	0.959	1.835	2.010	0.392
Std. Devn. %FS	0.068	0.311	0.231	0.736	0.612	0.117
Average error %FS	-0.004	0.042	0.085	-0.040	0.062	0.023
Ratio of absolute largest error to Std. Devn.	3.80	2.92	4.14	2.49	3.29	3.34
# terms	52	42	38	37	32	50

Matrix "4" (Mod-A of "optimum")	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.205	0.828	0.969	2.151	1.399	0.315
MIN error %FS	-0.275	-0.733	-0.512	-1.983	-2.291	-0.301
Absolute largest error %FS	0.275	0.828	0.969	2.151	2.291	0.315
Std. Devn. %FS	0.062	0.304	0.242	0.810	0.632	0.109
Average error %FS	-0.007	0.017	0.068	-0.070	-0.043	-0.004
Ratio of absolute largest error to Std. Devn.	4.42	2.72	4.01	2.66	3.63	2.89
# terms	32	28	26	14	17	27

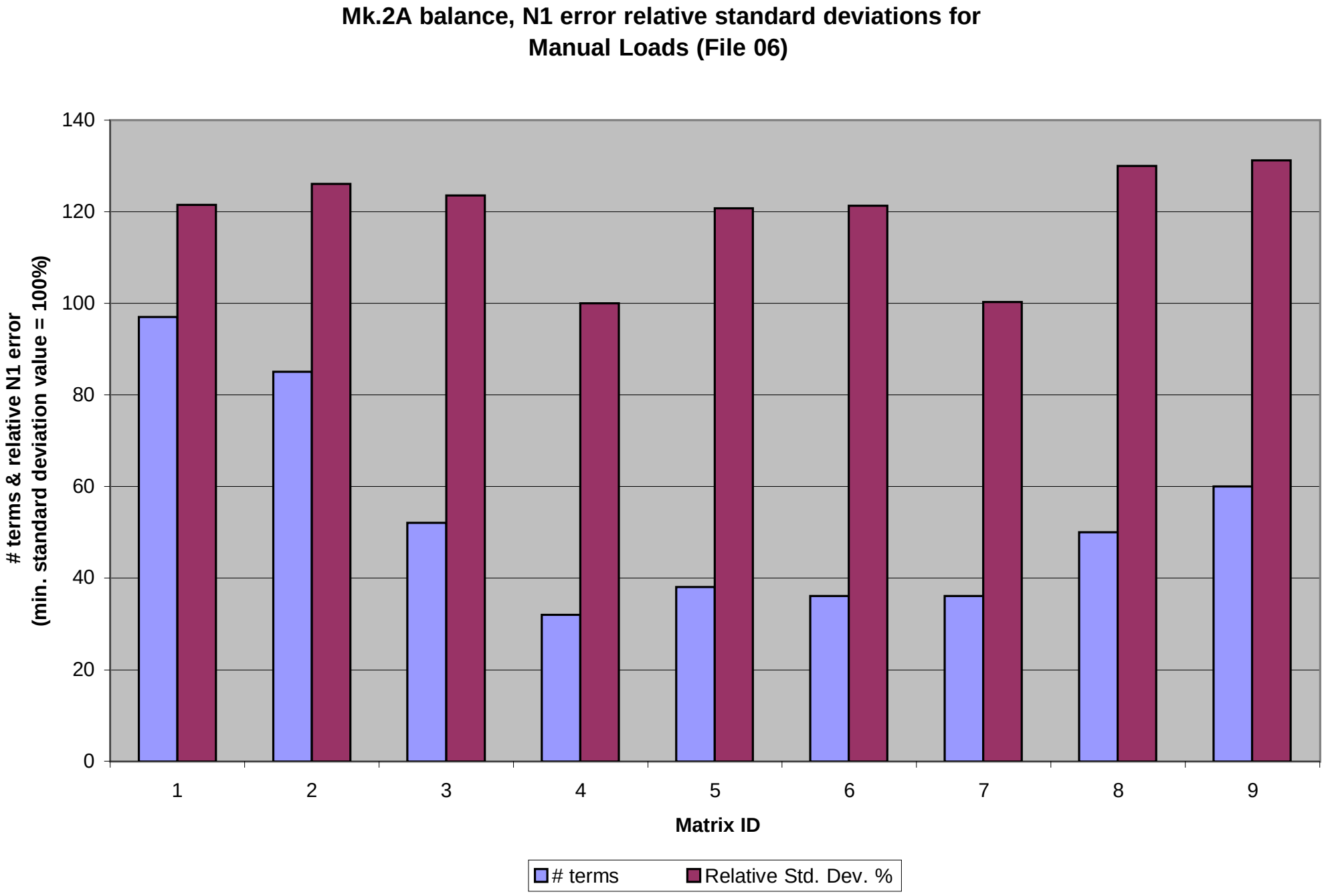
Matrix "5" (Mod-A2 of "optimum")	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.179	0.858	0.984	1.478	1.259	0.347
MIN error %FS	-0.271	-0.740	-0.483	-2.304	-2.185	-0.249
Absolute largest error %FS	0.271	0.858	0.984	2.304	2.185	0.347
Std. Devn. %FS	0.059	0.293	0.237	0.789	0.593	0.110
Average error %FS	-0.015	0.010	0.105	-0.174	-0.025	0.007
Ratio of absolute largest error to Std. Devn.	4.56	2.92	4.16	2.92	3.68	3.15
# terms	38	26	32	24	19	31

Matrix "6" (Mod-A3 of "optimum")	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.178	0.855	0.978	1.940	1.240	0.347
MIN error %FS	-0.270	-0.738	-0.502	-2.051	-2.219	-0.249
Absolute largest error %FS	0.270	0.855	0.978	2.051	2.219	0.347
Std. Devn. %FS	0.059	0.293	0.235	0.789	0.596	0.110
Average error %FS	-0.014	0.009	0.072	-0.056	-0.072	0.006
Ratio of absolute largest error to Std. Devn.	4.55	2.92	4.16	2.60	3.73	3.15
# terms	36	26	30	20	15	31

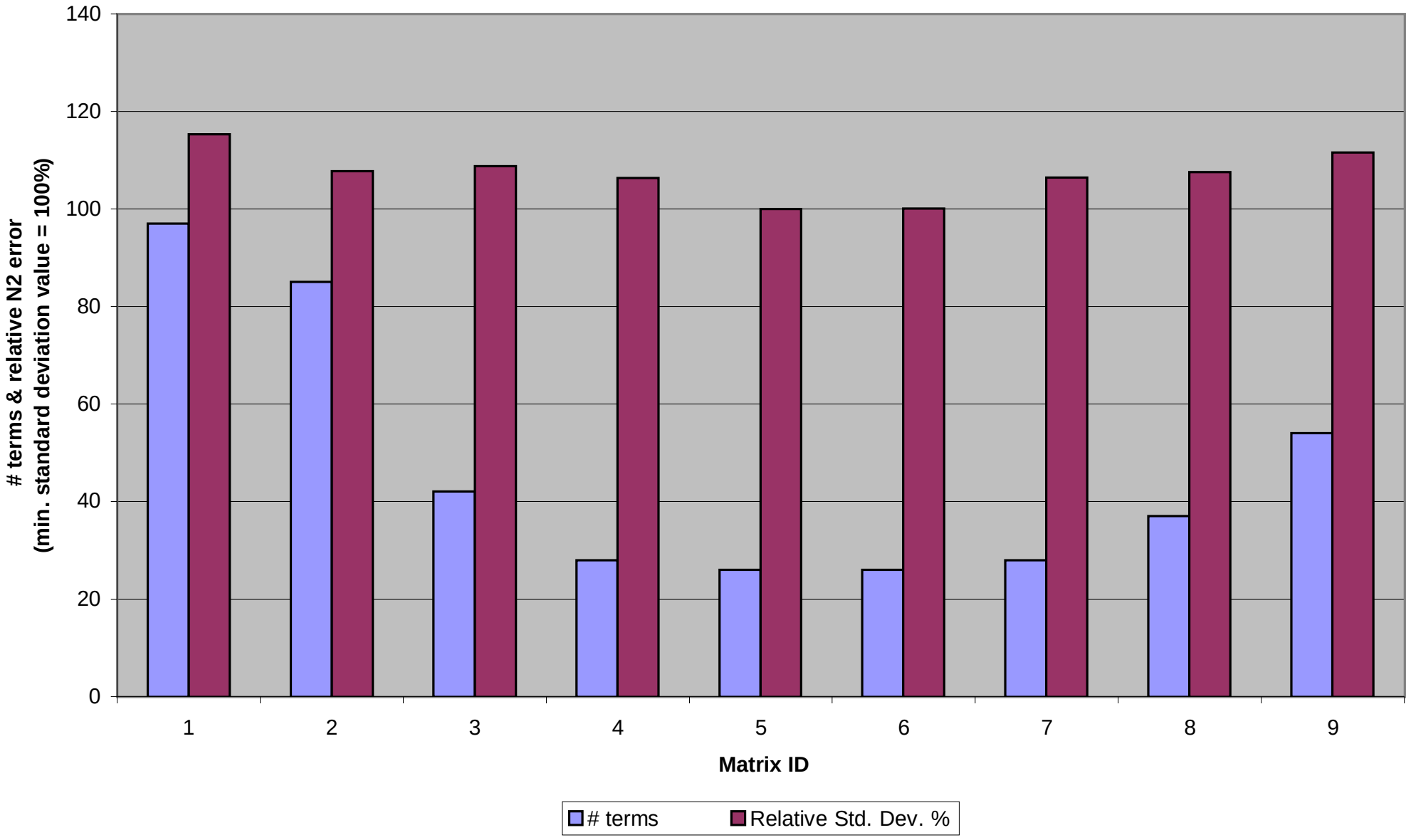
Matrix "7" (Mod-B of "optimum")	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.206	0.829	0.969	2.166	1.399	0.314
MIN error %FS	-0.285	-0.732	-0.532	-1.985	-2.291	-0.302
Absolute largest error %FS	0.285	0.829	0.969	2.166	2.291	0.314
Std. Devn. %FS	0.064	0.304	0.243	0.808	0.632	0.109
Average error %FS	-0.007	0.017	0.069	-0.054	-0.043	-0.004
Ratio of absolute largest error to Std. Devn.	4.45	2.72	3.98	2.68	3.63	2.88
# terms	36	28	26	22	17	27

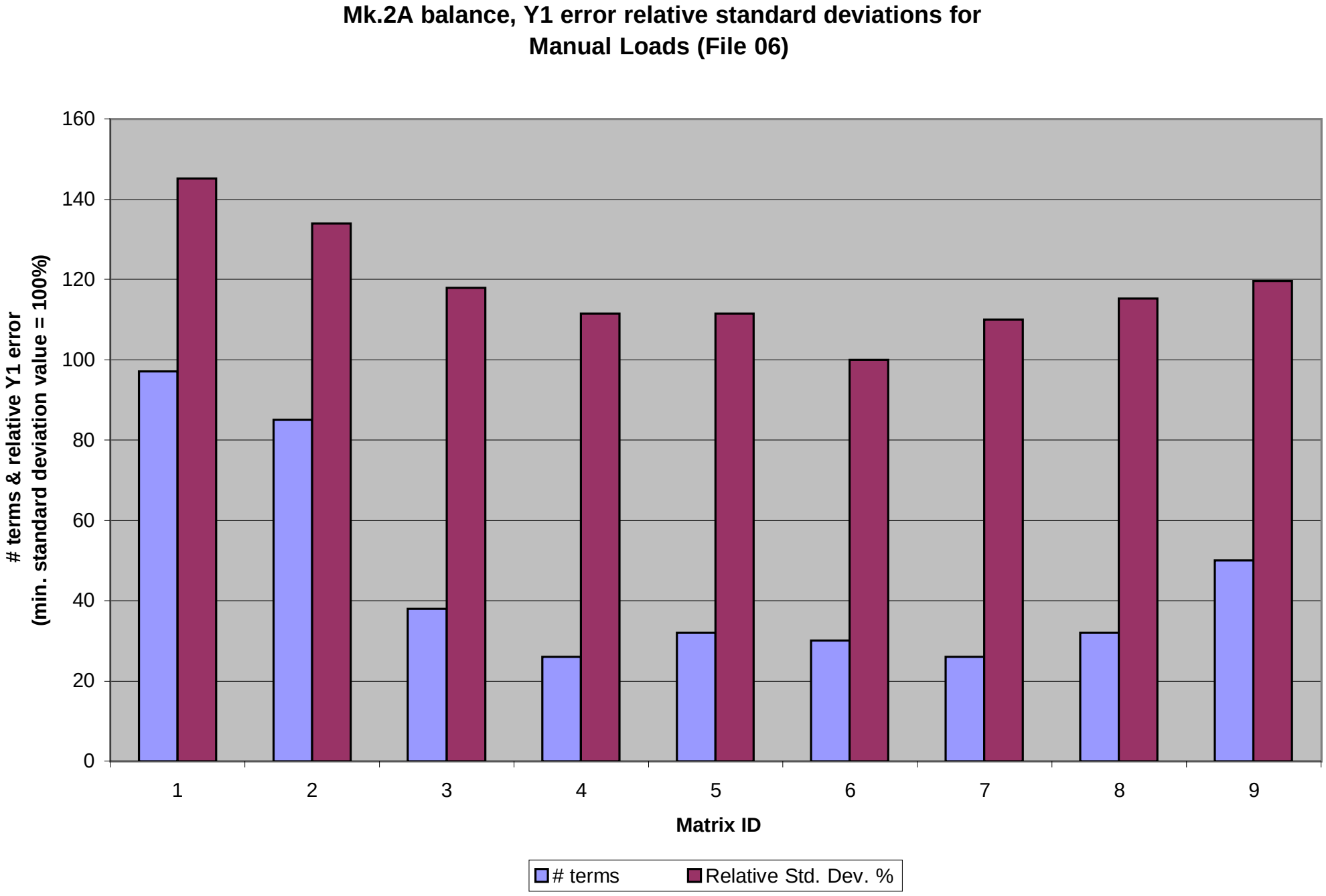
Matrix "8" (Mod-C of "optimum")	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.202	0.864	0.971	2.087	1.491	0.373
MIN error %FS	-0.282	-0.656	-0.362	-1.994	-2.080	-0.217
Absolute largest error %FS	0.282	0.864	0.971	2.087	2.080	0.373
Std. Devn. %FS	0.072	0.305	0.246	0.806	0.605	0.114
Average error %FS	-0.003	0.027	0.087	-0.066	-0.009	0.018
Ratio of absolute largest error to Std. Devn.	3.92	2.83	3.95	2.59	3.44	3.28
# terms	50	37	32	33	20	47

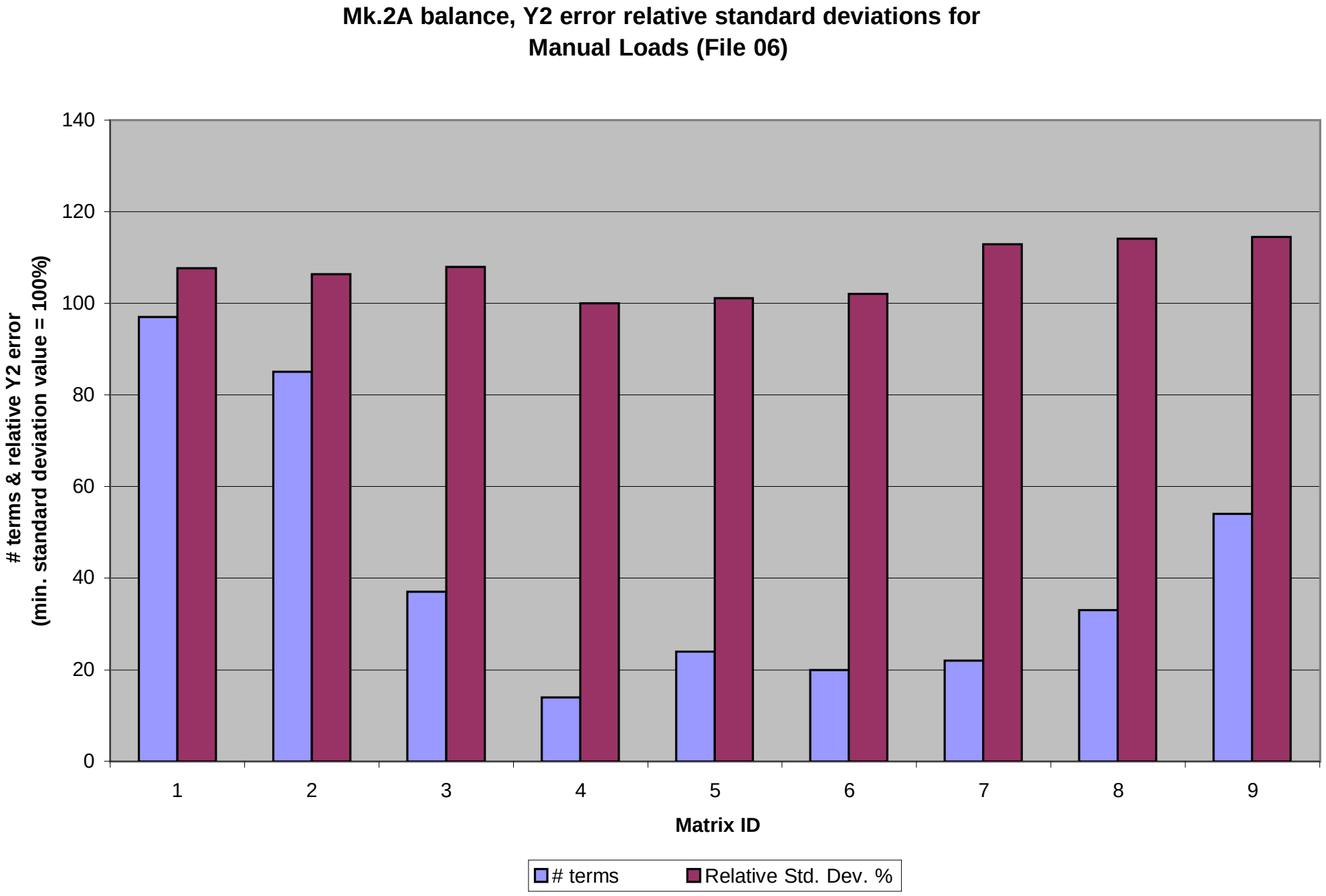
Matrix "9" (Mod-D of "optimum")	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.199	0.903	0.944	2.162	1.865	0.375
MIN error %FS	-0.285	-0.610	-0.351	-2.043	-2.020	-0.226
Absolute largest error %FS	0.285	0.903	0.944	2.162	2.020	0.375
Std. Devn. %FS	0.071	0.311	0.240	0.798	0.628	0.114
Average error %FS	-0.004	0.033	0.086	-0.070	0.062	0.019
Ratio of absolute largest error to Std. Devn.	4.01	2.90	3.93	2.71	3.22	3.28
# terms	60	54	50	54	60	63

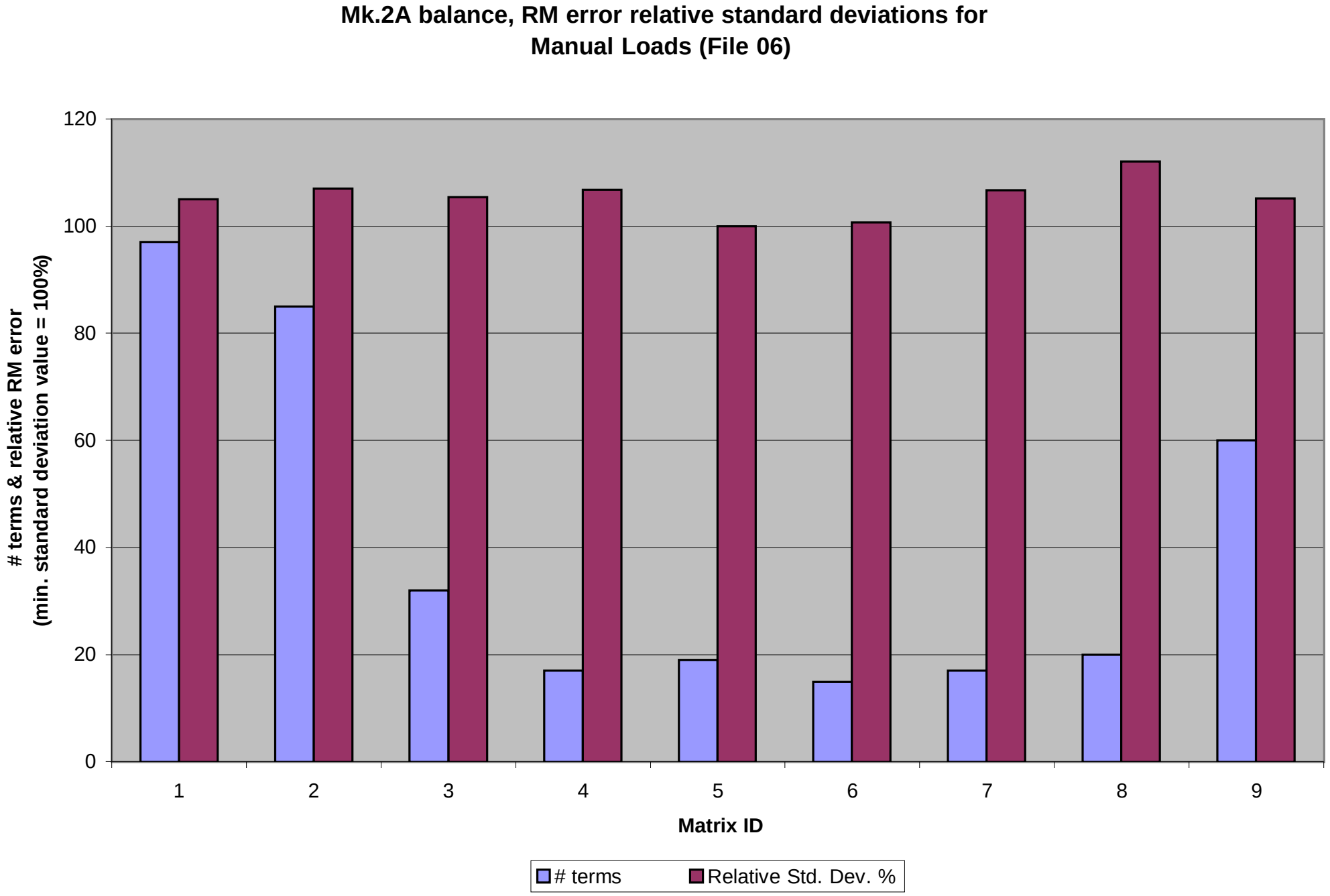

Mk.2A balance, N1 error relative standard deviations for Manual Loads (File 06)
terms & relative N1 error (min. standard deviation value = 100%)
140
120
100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
Matrix ID
terms
Relative Std. Dev. %

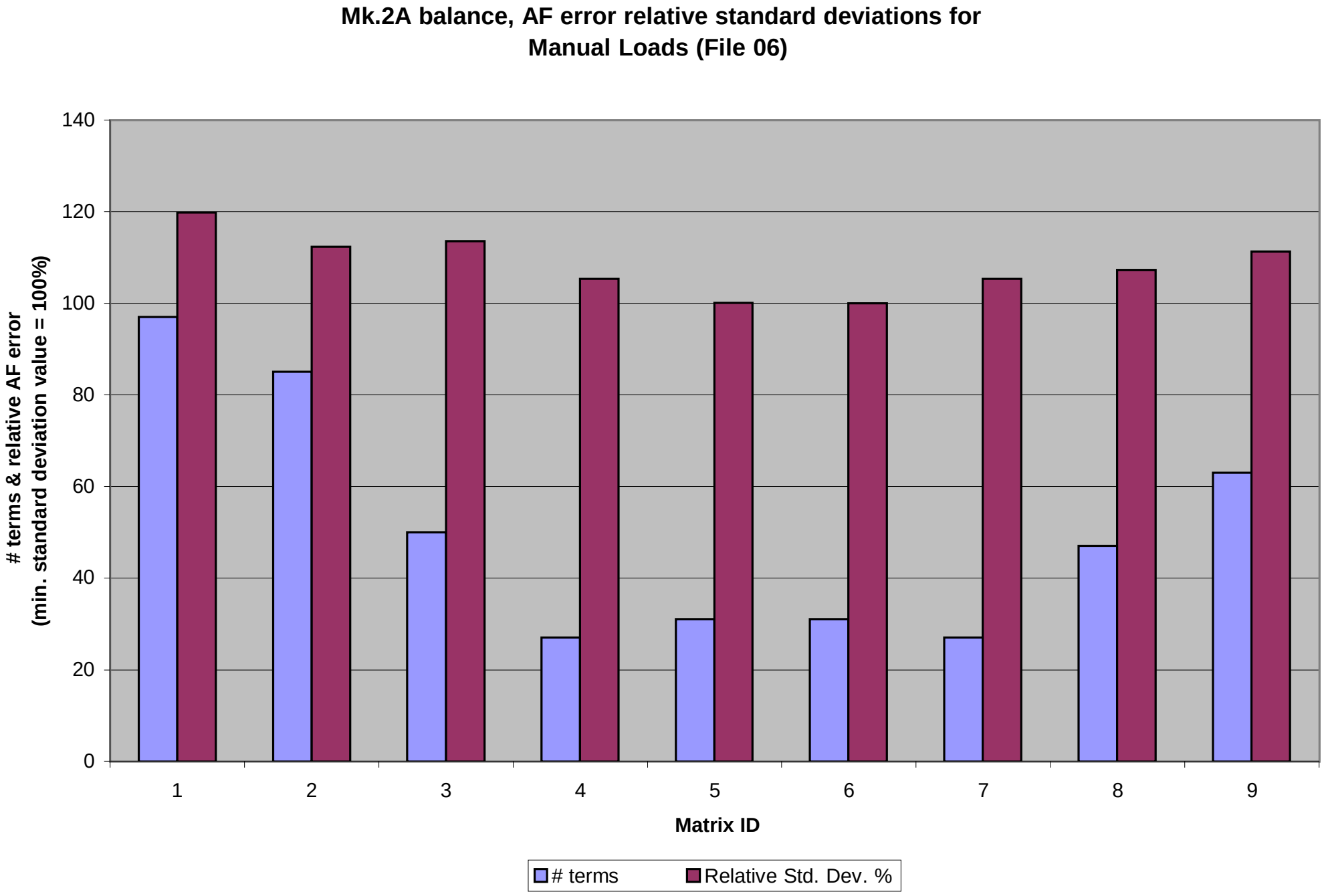
Mk.2A balance, N2 error relative standard deviations for Manual Loads (File 06)




Mk.2A balance, Y1 error relative standard deviations for Manual Loads (File 06)
terms & relative Y1 error (min. standard deviation value = 100%)
160
140
120
100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
Matrix ID
terms
Relative Std. Dev. %


Mk.2A balance, Y2 error relative standard deviations for Manual Loads (File 06)
terms & relative Y2 error (min. standard deviation value = 100%)
140
120
100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
Matrix ID
terms
Relative Std. Dev. %


Mk.2A balance, RM error relative standard deviations for
Manual Loads (File 06)
terms & relative RM error
(min. standard deviation value = 100%)
120
100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
Matrix ID
terms
Relative Std. Dev. %


Mk.2A balance, AF error relative standard deviations for Manual Loads (File 06)
terms & relative AF error (min. standard deviation value = 100%)
140
120
100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
Matrix ID
terms
Relative Std. Dev. %

Error statistics summary from loads calculation of the Mk.2A generic 6-component W/T Test Loads File 03 using different matrices.

Matrix "1" (6x97)	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.022	0.913	0.969	2.228	2.867	0.317
MIN error %FS	-0.478	-1.161	-0.192	-3.821	-2.998	-0.412
Absolute largest error %FS	0.478	1.161	0.969	3.821	2.998	0.412
Std. Devn. %FS	0.104	0.467	0.226	1.110	1.205	0.167
Average error %FS	-0.256	-0.127	0.191	-0.571	-0.245	-0.051
Ratio of absolute largest error to Std. Devn.	4.60	2.48	4.28	3.44	2.49	2.46
# terms	97	97	97	97	97	97

Matrix "2" (6x85)	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.088	0.636	0.849	2.411	2.435	0.220
MIN error %FS	-0.477	-1.086	-0.291	-3.427	-3.280	-0.418
Absolute largest error %FS	0.477	1.086	0.849	3.427	3.280	0.418
Std. Devn. %FS	0.108	0.437	0.209	1.097	1.228	0.157
Average error %FS	-0.233	-0.262	0.099	-0.360	-0.760	-0.081
Ratio of absolute largest error to Std. Devn.	4.43	2.49	4.07	3.12	2.67	2.67
# terms	85	85	85	85	85	85

Matrix "3" (Norbert Ulbrich "optimum")	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.099	0.673	0.512	2.999	2.384	0.228
MIN error %FS	-0.450	-1.062	-0.570	-2.176	-3.290	-0.415
Absolute largest error %FS	0.450	1.062	0.570	2.999	3.290	0.415
Std. Devn. %FS	0.106	0.441	0.184	1.114	1.210	0.158
Average error %FS	-0.218	-0.260	-0.075	0.506	-0.763	-0.075
Ratio of absolute largest error to Std. Devn.	4.26	2.41	3.10	2.69	2.72	2.62
# terms	52	42	38	37	32	50

Matrix "4" (Mod-A of "optimum")	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.146	0.633	0.284	2.669	2.363	0.180
MIN error %FS	-0.365	-1.102	-0.742	-2.240	-3.427	-0.484
Absolute largest error %FS	0.365	1.102	0.742	2.669	3.427	0.484
Std. Devn. %FS	0.085	0.431	0.174	1.032	1.226	0.147
Average error %FS	-0.203	-0.279	-0.188	0.410	-0.966	-0.176
Ratio of absolute largest error to Std. Devn.	4.27	2.55	4.27	2.59	2.80	3.30
# terms	32	28	26	14	17	27

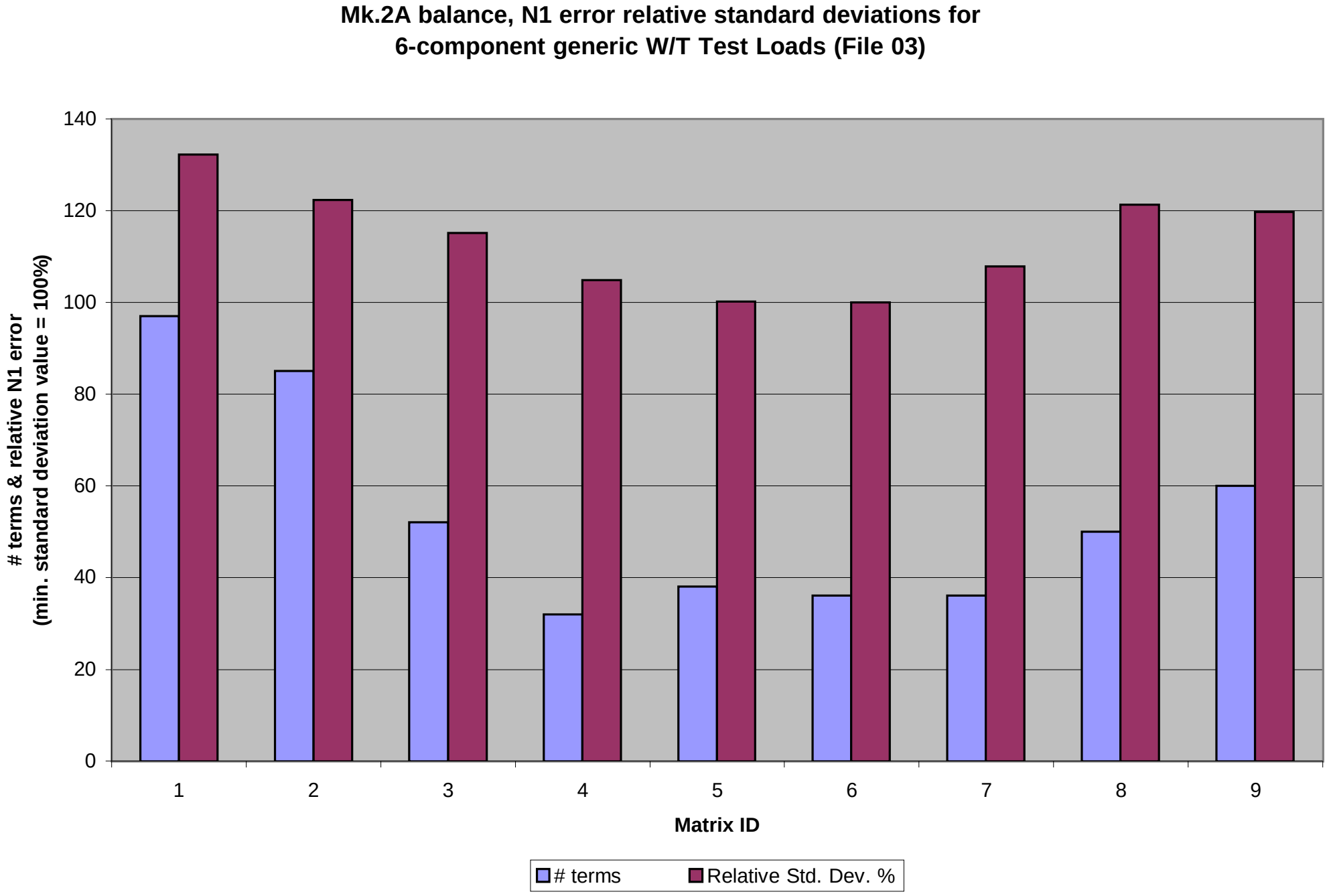
Matrix "5" (Mod-A2 of "optimum")	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.073	0.562	0.594	2.431	1.878	0.229
MIN error %FS	-0.432	-1.103	-0.380	-2.573	-3.466	-0.398
Absolute largest error %FS	0.432	1.103	0.594	2.573	3.466	0.398
Std. Devn. %FS	0.103	0.405	0.174	1.043	1.148	0.140
Average error %FS	-0.242	-0.305	-0.003	0.148	-1.108	-0.107
Ratio of absolute largest error to Std. Devn.	4.18	2.72	3.42	2.47	3.02	2.85
# terms	38	26	32	24	19	31

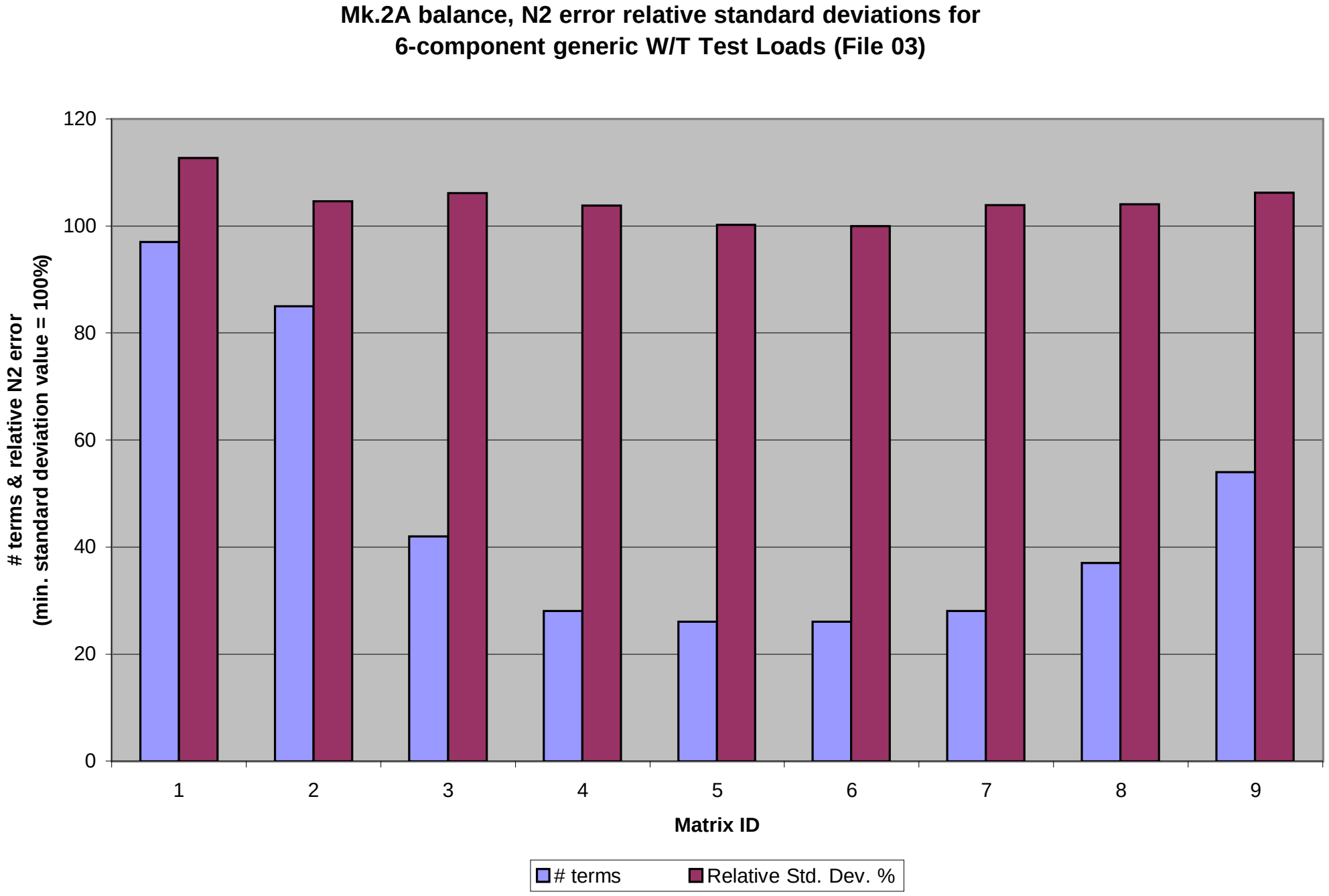
Matrix "6" (Mod-A3 of "optimum")	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.073	0.562	0.337	2.855	1.733	0.228
MIN error %FS	-0.431	-1.104	-0.567	-1.972	-3.610	-0.399
Absolute largest error %FS	0.431	1.104	0.567	2.855	3.610	0.399
Std. Devn. %FS	0.104	0.406	0.156	1.053	1.156	0.139
Average error %FS	-0.240	-0.305	-0.113	0.568	-1.225	-0.108
Ratio of absolute largest error to Std. Devn.	4.16	2.72	3.64	2.71	3.12	2.86
# terms	36	26	30	20	15	31

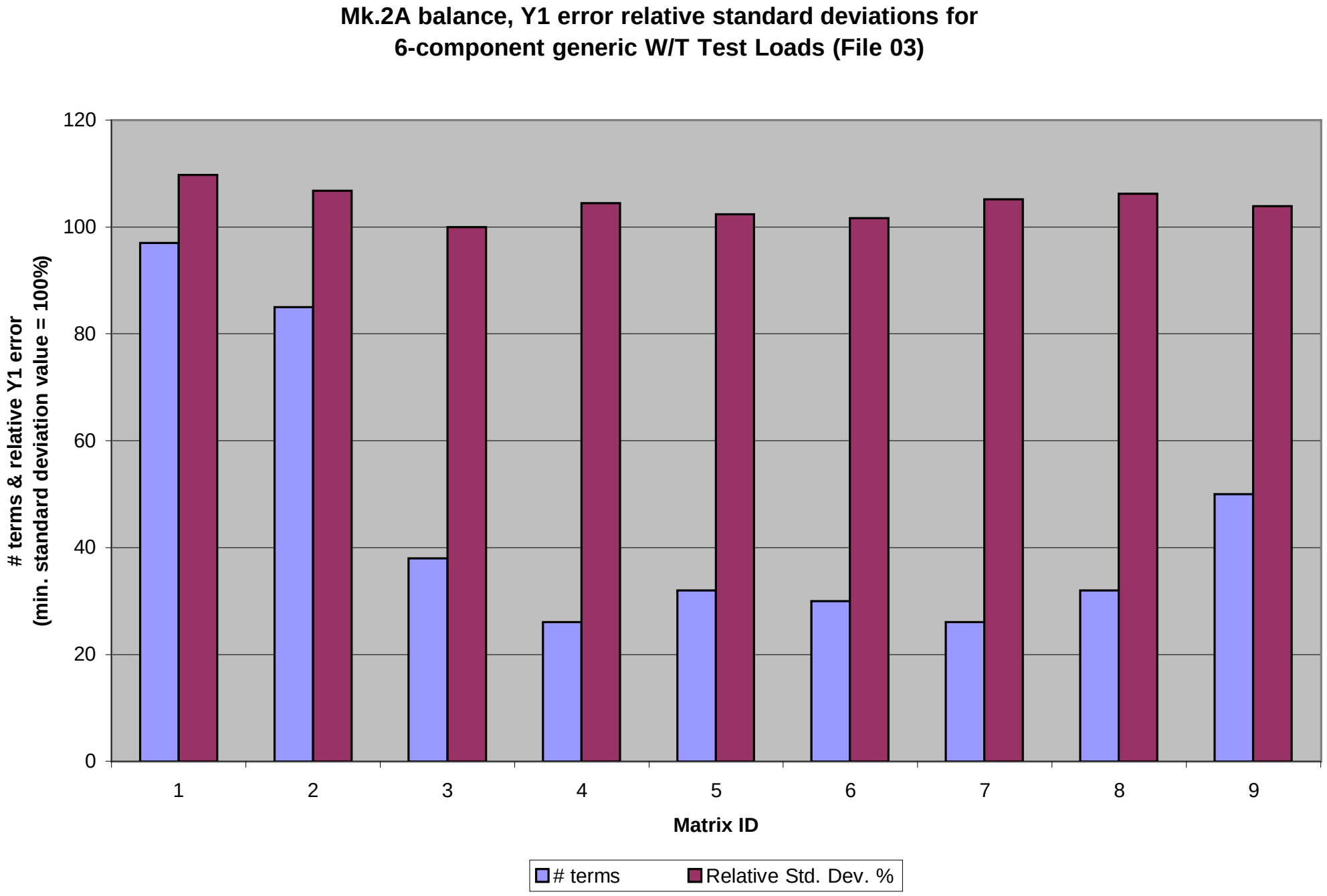
Matrix "7" (Mod-B of "optimum")	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.135	0.635	0.297	2.602	2.359	0.180
MIN error %FS	-0.371	-1.102	-0.738	-2.436	-3.429	-0.484
Absolute largest error %FS	0.371	1.102	0.738	2.602	3.429	0.484
Std. Devn. %FS	0.086	0.432	0.171	1.165	1.225	0.147
Average error %FS	-0.207	-0.279	-0.187	0.436	-0.967	-0.176
Ratio of absolute largest error to Std. Devn.	4.33	2.55	4.31	2.23	2.80	3.29
# terms	36	28	26	22	17	27

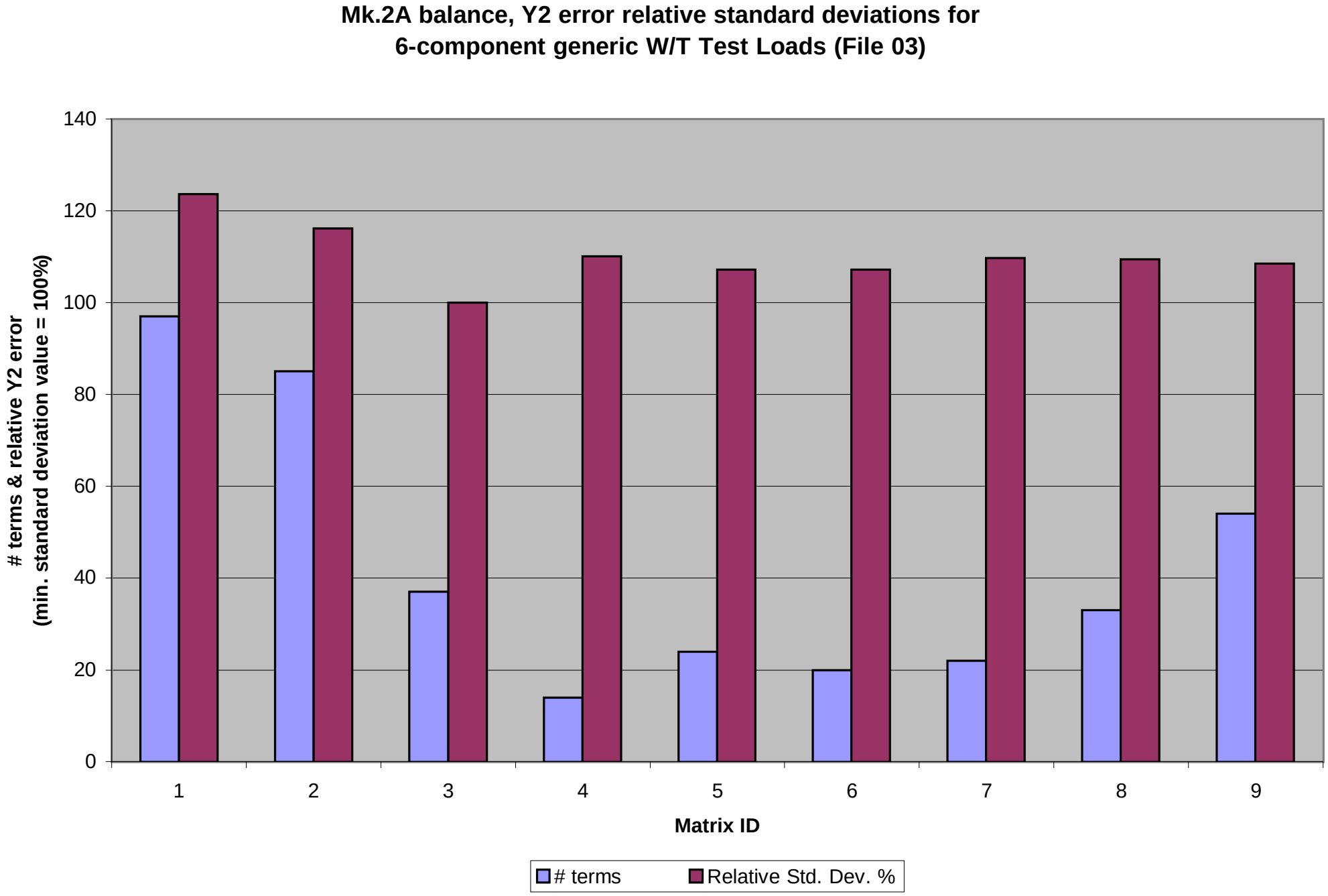
Matrix "8" (Mod-C of "optimum")	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.129	0.676	0.370	3.080	2.462	0.248
MIN error %FS	-0.468	-1.075	-0.689	-2.539	-3.605	-0.417
Absolute largest error %FS	0.468	1.075	0.689	3.080	3.605	0.417
Std. Devn. %FS	0.111	0.436	0.180	1.178	1.286	0.150
Average error %FS	-0.221	-0.246	-0.135	0.524	-1.021	-0.107
Ratio of absolute largest error to Std. Devn.	4.21	2.47	3.84	2.61	2.80	2.79
# terms	50	37	32	33	20	47

Matrix "9" (Mod-D of "optimum")	N1 (%FS)	N2 (%FS)	Y1 (%FS)	Y2 (%FS)	RM (%FS)	AF (%FS)
MAX error %FS	0.131	0.706	0.441	2.932	2.196	0.230
MIN error %FS	-0.473	-1.062	-0.687	-2.588	-3.299	-0.422
Absolute largest error %FS	0.473	1.062	0.687	2.932	3.299	0.422
Std. Devn. %FS	0.112	0.452	0.186	1.181	1.207	0.155
Average error %FS	-0.221	-0.251	-0.112	0.450	-0.866	-0.115
Ratio of absolute largest error to Std. Devn.	4.22	2.35	3.68	2.48	2.73	2.72
# terms	60	54	50	54	60	63

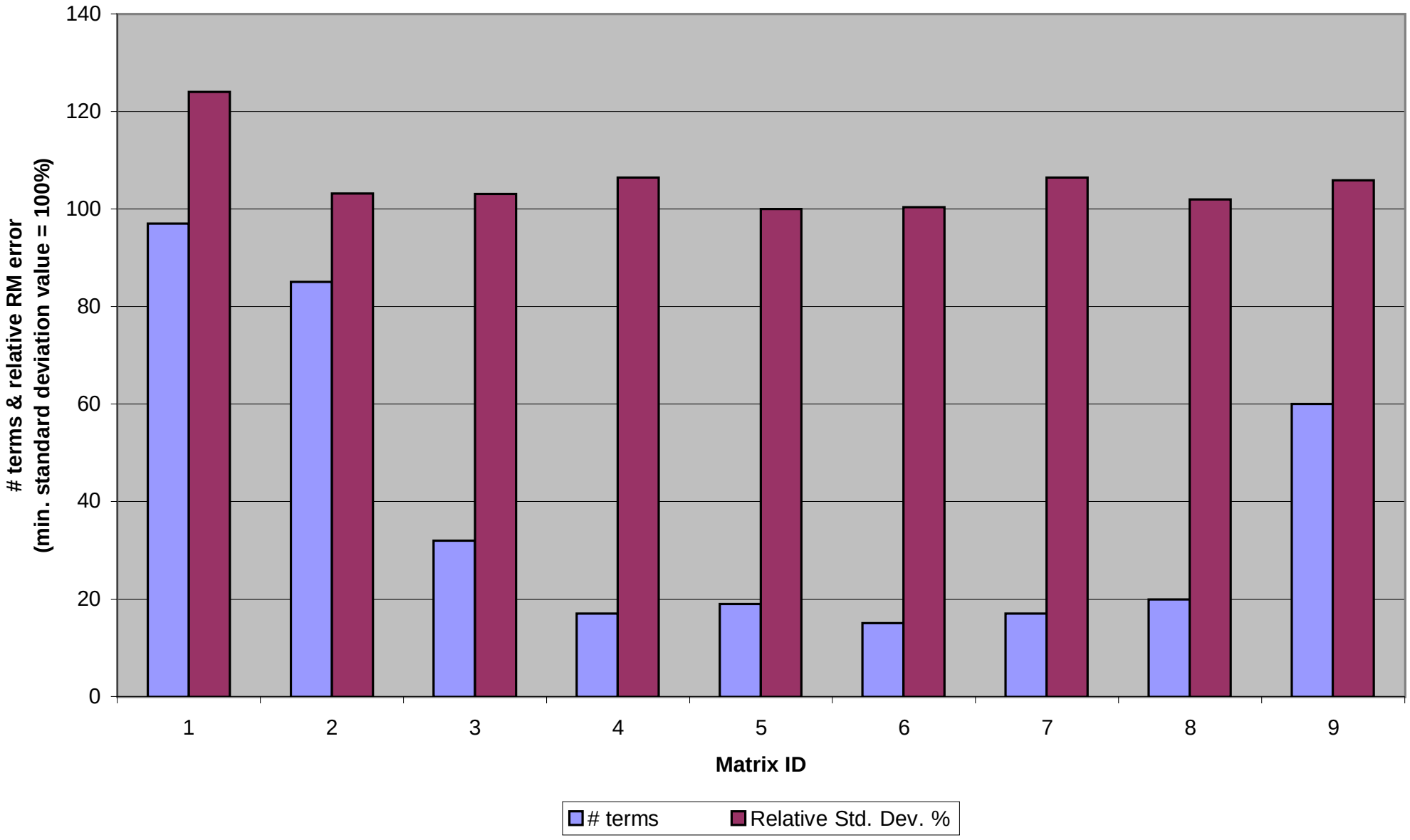

Mk.2A balance, N1 error relative standard deviations for
6-component generic W/T Test Loads (File 03)
terms & relative N1 error
(min. standard deviation value = 100%)
140
120
100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
Matrix ID
terms
Relative Std. Dev. %

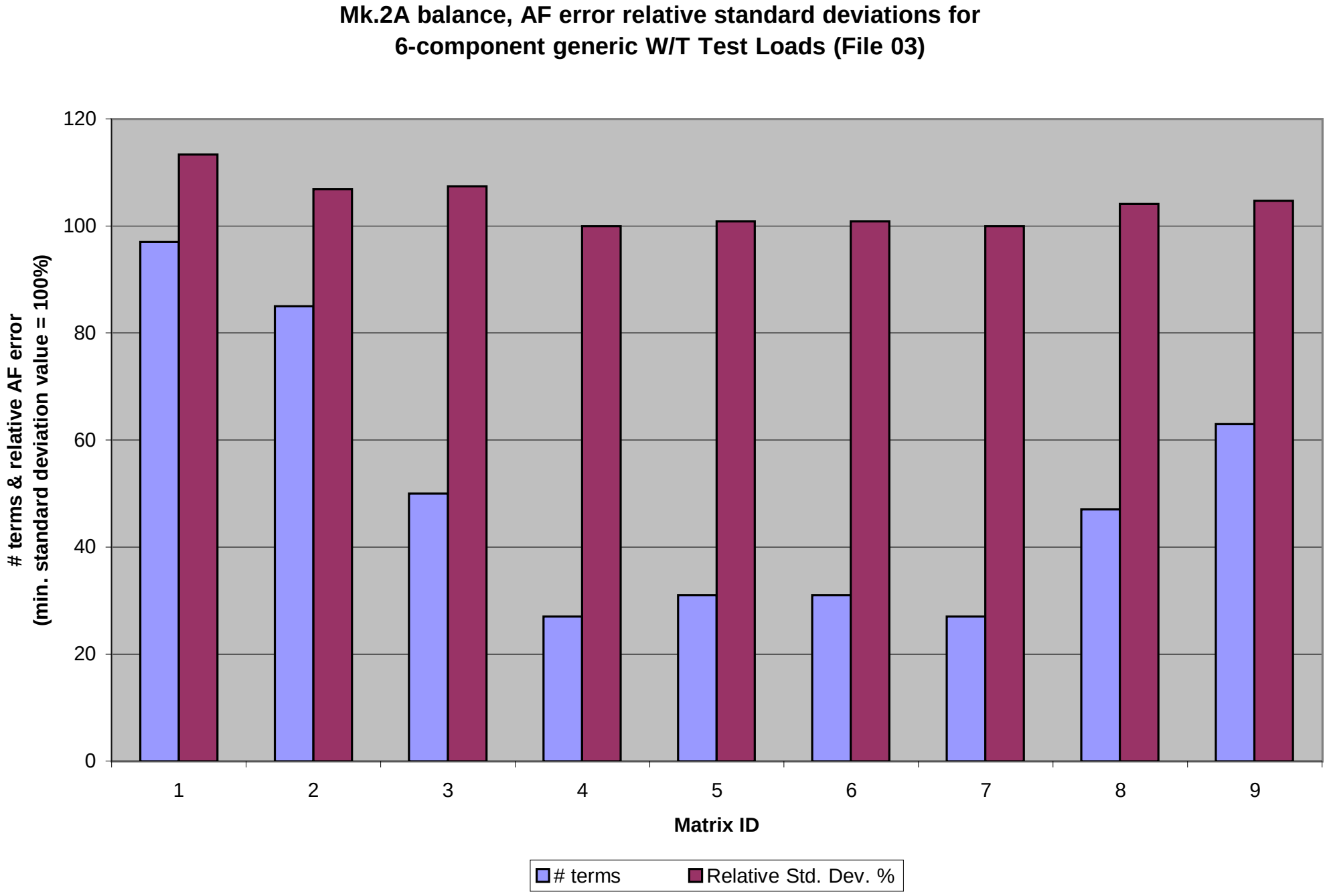

Mk.2A balance, N2 error relative standard deviations for
6-component generic W/T Test Loads (File 03)
terms & relative N2 error
(min. standard deviation value = 100%)
120
100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
Matrix ID
terms
Relative Std. Dev. %


Mk.2A balance, Y1 error relative standard deviations for
6-component generic W/T Test Loads (File 03)
terms & relative Y1 error
(min. standard deviation value = 100%)
120
100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
Matrix ID
terms
Relative Std. Dev. %


Mk.2A balance, Y2 error relative standard deviations for
6-component generic W/T Test Loads (File 03)
terms & relative Y2 error
(min. standard deviation value = 100%)
140
120
100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
Matrix ID
terms
Relative Std. Dev. %

Mk.2A balance, RM error relative standard deviations for 6-component generic W/T Test Loads (File 03)




Mk.2A balance, AF error relative standard deviations for
6-component generic W/T Test Loads (File 03)
terms & relative AF error
(min. standard deviation value = 100%)
120
100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
Matrix ID
terms
Relative Std. Dev. %