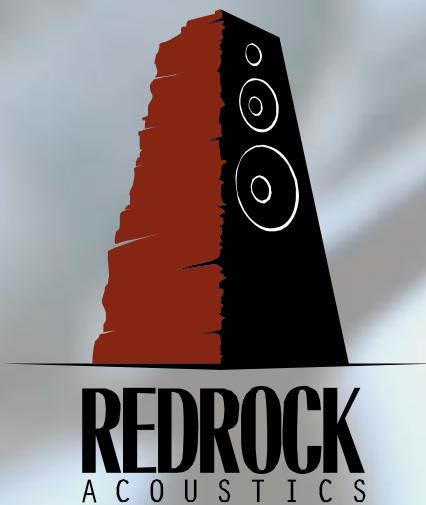


# ALMA International 2007 China Symposium

“Simulation of T/S Parameter Production Tolerances”

By Patrick Turnmire  
Redrock Acoustics



# “Simulation of T/S Parameter Production Tolerances”

Thiele / Small parameters (T/S), Frequency Response and Power Handling, are the primary evaluation standards for loudspeaker performance.

For production testing, both frequency response and power handling have clear standards and a good engineering basis for those standards.

Thiele / Small parameter standards, however are typically assigned arbitrarily with no consideration of their relationship to the parts' tolerance specifications that actually cause the parameter variance

- or to the real **performance** variations!

( System  $F_3$ , Tuning, SPL )

# “Simulation of T/S Parameter Production Tolerances”

A typical Tolerance Specification for T/S parameters might look like this:

Parameter	Value	Unit	Tolerance
$R_e$	6	Ohms	+/- 5%
$F_o$	60.3	Hz.	+/- 10%
$Q_{ts}$	.575		+/- 10%
$Q_{ms}$	6.0		+/- 10%
$V_{as}$	27.27	Liters	+/- 10%

- How these relate to the **Parts Specifications** is not considered!  
( How do parameters change when part values change? )
- How these relate to the **Performance** of the speaker is not considered!  
( What parameters are important for the performance? )

# “Simulation of T/S Parameter Production Tolerances”

## What we need to do is:

- Identify which parameters are important for performance.
- Identify how part changes affect parameters  
(especially the important ones)
- Set parameter tolerances that are based on reasonable parts tolerances.

# “Simulation of T/S Parameter Production Tolerances”

Which parameters are important for performance?

Performance is typically defined by:

System  $F_3$

Tuning (  $Q_{tc}$  for sealed and infinite baffle,  $F_b$  for vented )

Sensitivity

These are not defined by single parameters, rather by ratios of parameters:

$F_o / Q_{ts}$  ratio

$BL^2 / R_e$  ratio

Good control over these ratios, means good control over the performance of the system.

# “Simulation of T/S Parameter Production Tolerances”

How do part changes affect parameters?

**Speaker parts specifications are typically a combination of dimensions with tolerance values, and part-specific specifications such as DCR (coils), deflection (spiders) Fo (cones), etc.**

**Changes in parts values typically change more than one parameter.**

**For example:**

**Coil DCR affects every parameter**

**Cone Fo affects Fo, Qts Qes, Vas**

**Motor Dimensions affect Qe, Qts, BL, SPL**

# **“Simulation of T/S Parameter Production Tolerances”**

**In fact all of the speaker parts tolerances interact to produce a wide range of variance in the speaker parameters**

**To accurately calculate parameter variations based on the tolerances of individual parts you need to create a complex matrix of all of the important variables and their tolerances.**

**Then calculate how these variables affect every parameter through the full range of their tolerances.**

**Easy Right?**

**Fortunately....**

# “Simulation of T/S Parameter Production Tolerances”

## Parameter Tolerance Worksheet

Starting Values	Unit	Value
Sd	cm^2	216.42
BL	Tm	7.798
Mmd	g	15

Enter starting values and part specifications (BOLD values).

All other values are calculated.

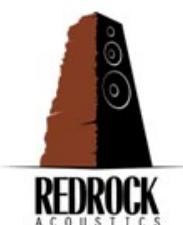
Part Specification	Unit	Standard	+%	-%	+ Value	- Value
Re (coil Dcr)	Ohm	6	5.00%	5.00%	6.30	5.70
Coil Mass	g	2.75				
Front Plate Thickness	mm	6	1.67%	1.67%	0.10	0.10
Front Plate Inside Diameter	mm	28.7	0.35%	0.00%	0.10	0.00
Pole Piece Diameter	mm	24.95	0.00%	0.40%	0.00	0.10
Magnet Outside Diameter	mm	100	0.00%	0.00%	0.00	0.00
Magnet Inside Diameter	mm	45	2.22%	2.22%	1.00	1.00
Magnet material Br Variance			0.00%	0.00%		
Cone Fo	Hz.	45	10.00%	10.00%	49.50	40.50
Cone +1/2 edge Mmd	g	8.6	0.00%	0.00%	8.60	8.60
Spider Deflection	mm	0.62	10.00%	10.00%	0.68	0.56
Mass for Deflection	g	100				
Qms		6.8	10.00%	10.00%	7.48	6.12
Glue Mass	g	1	5.00%	5.00%	1.05	0.95

Parameters are calculated based on the "Starting Values" and "Standard Part Specifications".

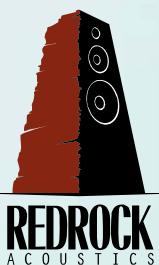
The Sealed Enclosure Predictions are calculated for the entered "Box Volume".

Parameters	Unit	Standard	+%	-%	+Value	-Value
Re	Ohm	6	5.0%	5.0%	6.30	5.70
Fo	Hz.	60.30	7.6%	7.0%	64.90	56.10
Qes		0.628	23.0%	14.4%	0.772	0.537
Qms		6.8	10.0%	10.0%	7.48	6.12
Qts		0.575	21.7%	14.1%	0.700	0.494
BL	Tm	7.798	1.6%	4.1%	7.93	7.48
BL^2 / Re		10.13	8.7%	12.5%	11.02	8.87
Fo/Qts		104.87	8.3%	11.6%	113.55	92.70
Mmd	g	15	1.3%	1.3%	15.19	14.81
Mms (FA)	g	16.80	1.1%	1.1%	16.99	16.61
Cms	m/N	4.15E-04	14.3%	12.7%	4.74E-04	3.62E-04
Vas	Liters	27.27	14.3%	12.7%	31.17	23.81
SPL 2.83V	dB	92.96	0.7%	1.0%	93.65	92.08
SPL 1W1m	dB	91.71	0.5%	0.7%	92.17	91.04

Sealed Enclosure						
Box Volume	Liter	10				
Qtc		1.110	16.0%	9.7%	1.287	1.002
F3	Hz.	87.82	1.8%	1.9%	89.39	86.17



Copyright Redrock Acoustics 2007



REDROCK  
ACOUSTICS

# “Simulation of T/S Parameter Production Tolerances”

## Input values

Starting Values	Unit	Value
Sd	cm^2	<b>216.42</b>
BL	Tm	<b>7.798</b>
Mmd	g	<b>15</b>

Enter starting values and part specifications (BOLD values).

All other values are calculated.

Part Specification	Unit	Standard	+%	-%	+ Value	- Value
Re (coil Dcr)	Ohm	<b>6</b>	<b>5.00%</b>	<b>5.00%</b>	6.30	5.70
Coil Mass	g	<b>2.75</b>				
Front Plate Thickness	mm	<b>6</b>	1.67%	1.67%	<b>0.10</b>	<b>0.10</b>
Front Plate Inside Diameter	mm	<b>28.7</b>	0.35%	0.00%	<b>0.10</b>	<b>0.00</b>
Pole Piece Diameter	mm	<b>24.95</b>	0.00%	0.40%	<b>0.00</b>	<b>0.10</b>
Magnet Outside Diameter	mm	<b>100</b>	0.00%	0.00%	<b>0.00</b>	<b>0.00</b>
Magnet Inside Diameter	mm	<b>45</b>	2.22%	2.22%	<b>1.00</b>	<b>1.00</b>
Magnet material Br Variance			<b>0.00%</b>	<b>0.00%</b>		
Cone Fo	Hz.	<b>45</b>	<b>10.00%</b>	<b>10.00%</b>	49.50	40.50
Cone +1/2 edge Mmd	g	<b>8.6</b>	<b>0.00%</b>	<b>0.00%</b>	8.60	8.60
Spider Deflection	mm	<b>0.62</b>	<b>10.00%</b>	<b>10.00%</b>	0.68	0.56
Mass for Deflection	g	<b>100</b>				
Qms		<b>6.8</b>	<b>10.00%</b>	<b>10.00%</b>	7.48	6.12
Glue Mass	g	<b>1</b>	<b>5.00%</b>	<b>5.00%</b>	1.05	0.95



# “Simulation of T/S Parameter Production Tolerances”

## Tolerance Calculations

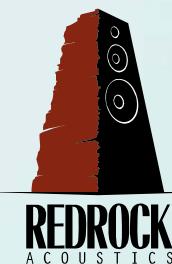
Parameters are calculated based on the "Starting Values" and "Standard Part Specifications".

The Sealed Enclosure Predictions are calculated for the entered "Box Volume".

Parameters	Unit	Standard	+%	-%	+Value	-Value
Re	Ohm	6	5.0%	5.0%	6.30	5.70
Fo	Hz.	60.30	7.6%	7.0%	64.90	56.10
Qes		0.628	23.0%	14.4%	0.772	0.537
Qms		6.8	10.0%	10.0%	7.48	6.12
Qts		0.575	21.7%	14.1%	0.700	0.494
BL	Tm	7.798	1.6%	4.1%	7.93	7.48
BL^2 / Re		10.13	8.7%	12.5%	11.02	8.87
Fo/Qts		104.87	8.3%	11.6%	113.55	92.70
Mmd	g	15	1.3%	1.3%	15.19	14.81
Mms (FA)	g	16.80	1.1%	1.1%	16.99	16.61
Cms	m/N	4.15E-04	14.3%	12.7%	4.74E-04	3.62E-04
Vas	Liters	27.27	14.3%	12.7%	31.17	23.81
SPL 2.83V	dB	92.96	0.7%	1.0%	93.65	92.08
SPL 1W1m	dB	91.71	0.5%	0.7%	92.17	91.04

### Sealed Enclosure

Box Volume	Liter	10				
Qtc		1.110	16.0%	9.7%	1.287	1.002
F3	Hz.	87.82	1.8%	1.9%	89.39	86.17



# “Simulation of T/S Parameter Production Tolerances”

## Coil DCR Change of +/- 5 %

### Parameter Tolerance Worksheet

Starting Values	Unit	Value
Sd	cm^2	216.42
BL	Tm	7.798
Mmd	g	15

Enter starting values and part specifications (BOLD values).

All other values are calculated.

Part Specification	Unit	Standard	+%	-%	+ Value	- Value
Re (coil Dcr)	Ohm	6	5.00%	5.00%	6.30	5.70
Coil Mass	g	2.75				
Front Plate Thickness	mm	6	0.00%	0.00%	0.00	0.00
Front Plate Inside Diameter	mm	28.7	0.00%	0.00%	0.00	0.00
Pole Piece Diameter	mm	24.95	0.00%	0.00%	0.00	0.00
Magnet Outside Diameter	mm	100	0.00%	0.00%	0.00	0.00
Magnet Inside Diameter	mm	45	0.00%	0.00%	0.00	0.00
Magnet material Br Variance			0.00%	0.00%		
Cone Fo	Hz.	45	0.00%	0.00%	45.00	45.00
Cone +1/2 edge Mmd	g	8.6	0.00%	0.00%	8.60	8.60
Spider Deflection	mm	0.62	0.00%	0.00%	0.62	0.62
Mass for Deflection	g	100				
Qms		6.8	0.00%	0.00%	6.80	6.80
Glue Mass	g	1	0.00%	0.00%	1.00	1.00

Parameters are calculated based on the "Starting Values" and "Standard Part Specifications".

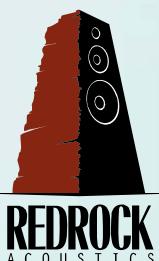
The Sealed Enclosure Predictions are calculated for the entered "Box Volume".

Parameters	Unit	Standard	+%	-%	+Value	-Value
Re	Ohm	6	5.0%	5.0%	6.30	5.70
Fo	Hz.	60.30	0.4%	0.4%	60.55	60.06
Qes		0.628	5.4%	5.4%	0.662	0.594
Qms		6.8	0.0%	0.0%	6.8	6.8
Qts		0.575	4.9%	5.0%	0.603	0.547
BL	Tm	7.798	0.0%	0.0%	7.80	7.80
BL <sup>2</sup> / Re		10.13	5.3%	4.8%	10.67	9.65
Fo/Qts		104.87	4.8%	4.3%	109.89	100.34
Mmd	g	15	0.9%	0.9%	15.14	14.86
Mms (FA)	g	16.80	0.8%	0.8%	16.94	16.66
Cms	m/N	4.15E-04	0.0%	0.0%	4.15E-04	4.15E-04
Vas	Liters	27.27	0.0%	0.0%	27.27	27.27
SPL 2.83V	dB	92.96	0.6%	0.5%	93.48	92.47
SPL 1W1m	dB	91.71	0.3%	0.3%	92.00	91.43

Sealed Enclosure						
Box Volume	Liter	10				
Otc		1.110	4.9%	5.0%	1.165	1.055
F3	Hz.	87.82	1.5%	1.2%	89.12	86.79



Copyright Redrock Acoustics 2007



# “Simulation of T/S Parameter Production Tolerances”

## Cone F<sub>o</sub> +/- 10% & Spider Deflection +/- 15%

### Parameter Tolerance Worksheet

Starting Values	Unit	Value
Sd	cm <sup>2</sup>	216.42
BL	Tm	7.798
Mmd	g	15

Enter starting values and part specifications (BOLD values).

All other values are calculated.

Part Specification	Unit	Standard	+%	-%	+ Value	- Value
Re (coil Dcr)	Ohm	6	0.00%	0.00%	6.00	6.00
Coil Mass	g	2.75				
Front Plate Thickness	mm	6	0.00%	0.00%	0.00	0.00
Front Plate Inside Diameter	mm	28.7	0.00%	0.00%	0.00	0.00
Pole Piece Diameter	mm	24.95	0.00%	0.00%	0.00	0.00
Magnet Outside Diameter	mm	100	0.00%	0.00%	0.00	0.00
Magnet Inside Diameter	mm	45	0.00%	0.00%	0.00	0.00
Magnet material Br Variance			0.00%	0.00%		
Cone F <sub>o</sub>	Hz.	45	10.00%	10.00%	49.50	40.50
Cone +1/2 edge Mmd	g	8.6	0.00%	0.00%	8.60	8.60
Spider Deflection	mm	0.62	15.00%	15.00%	0.71	0.53
Mass for Deflection	g	100				
Qms		6.8	0.00%	0.00%	6.80	6.80
Glue Mass	g	1	0.00%	0.00%	1.00	1.00

Parameters are calculated based on the "Starting Values" and "Standard Part Specifications".

The Sealed Enclosure Predictions are calculated for the entered "Box Volume".

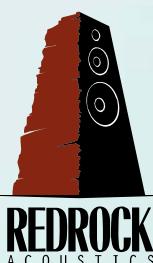
Parameters	Unit	Standard	+%	-%	+Value	-Value
Re	Ohm	6	0.0%	0.0%	6.00	6.00
F <sub>o</sub>	Hz.	60.30	9.0%	7.9%	65.73	55.57
Qes		0.628	9.0%	7.9%	0.685	0.579
Qms		6.8	0.0%	0.0%	6.8	6.8
Qts		0.575	8.2%	7.2%	0.622	0.533
BL	Tm	7.798	0.0%	0.0%	7.80	7.80
BL <sup>2</sup> / Re		10.13	0.0%	0.0%	10.13	10.13
F <sub>o</sub> /Qts		104.87	0.7%	0.8%	104.18	105.67
Mmd	g	15	0.0%	0.0%	15.00	15.00
Mms (FA)	g	16.80	0.0%	0.0%	16.80	16.80
Cms	m/N	4.15E-04	17.8%	15.8%	4.88E-04	3.49E-04
Vas	Liters	27.27	17.8%	15.8%	32.12	22.96
SPL 2.83V	dB	92.96	0.0%	0.0%	92.96	92.96
SPL 1W1m	dB	91.71	0.0%	0.0%	91.71	91.71

### Sealed Enclosure

Box Volume	Liter	10				
Qtc		1.110	1.7%	1.4%	1.129	1.095
F3	Hz.	87.82	1.6%	1.9%	86.45	89.48



Copyright Redrock Acoustics 2007



# “Simulation of T/S Parameter Production Tolerances”

## Typical Magnet Part Tolerances

### Parameter Tolerance Worksheet

Starting Values	Unit	Value
Sd	cm <sup>2</sup>	216.42
BL	Tm	7.798
Mmd	g	15

Enter starting values and part specifications (BOLD values).

All other values are calculated.

Part Specification	Unit	Standard	+%	-%	+ Value	- Value
Re (coil Dcr)	Ohm	6	0.00%	0.00%	6.00	6.00
Coil Mass	g	2.75				
Front Plate Thickness	mm	6	1.67%	1.67%	0.10	0.10
Front Plate Inside Diameter	mm	28.7	0.17%	0.00%	0.05	0.00
Pole Piece Diameter	mm	24.95	0.00%	0.20%	0.00	0.05
Magnet Outside Diameter	mm	100	0.50%	0.50%	0.50	0.50
Magnet Inside Diameter	mm	45	1.11%	1.11%	0.50	0.50
Magnet material Br Variance			2.00%	2.00%		
Cone Fo	Hz.	45	0.00%	0.00%	45.00	45.00
Cone +1/2 edge Mmd	g	8.6	0.00%	0.00%	8.60	8.60
Spider Deflection	mm	0.62	0.00%	0.00%	0.62	0.62
Mass for Deflection	g	100				
Qms		6.8	0.00%	0.00%	6.80	6.80
Glue Mass	g	1	0.00%	0.00%	1.00	1.00

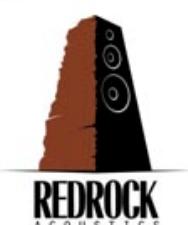
Parameters are calculated based on the "Starting Values" and "Standard Part Specifications".

The Sealed Enclosure Predictions are calculated for the entered "Box Volume".

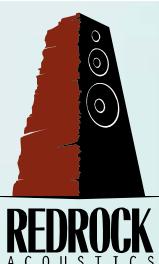
Parameters	Unit	Standard	+%	-%	+Value	-Value
Re	Ohm	6	0.0%	0.0%	6.00	6.00
Fo	Hz.	60.30	0.0%	0.0%	60.30	60.30
Qes		0.628	11.8%	7.8%	0.702	0.579
Qms		6.8	0.0%	0.0%	6.8	6.8
Qts		0.575	10.7%	7.2%	0.636	0.534
BL	Tm	7.798	4.1%	5.4%	8.12	7.38
BL <sup>2</sup> / Re		10.13	8.4%	10.5%	10.99	9.07
Fo/Qts		104.87	7.7%	9.6%	112.97	94.77
Mmd	g	15	0.0%	0.0%	15.00	15.00
Mms (FA)	g	16.80	0.0%	0.0%	16.80	16.80
Cms	m/N	4.15E-04	0.0%	0.0%	4.15E-04	4.15E-04
Vas	Liters	27.27	0.0%	0.0%	27.27	27.27
SPL 2.83V	dB	92.96	0.4%	0.5%	93.32	92.48
SPL 1W1m	dB	91.71	0.4%	0.5%	92.06	91.23

### Sealed Enclosure

Box Volume	Liter	10				
Otc		1.110	10.7%	7.2%	1.229	1.031
F3	Hz.	87.82	2.9%	3.1%	90.35	85.10



Copyright Redrock Acoustics 2007



REDROCK  
ACOUSTICS

# “Simulation of T/S Parameter Production Tolerances”

## Complete set of Typical Tolerances

Parameter Tolerance Worksheet

Starting Values	Unit	Value
Sd	cm^2	216.42
BL	Tm	7.798
Mmd	g	15

Enter starting values and part specifications (BOLD values).

All other values are calculated.

Part Specification	Unit	Standard	+%	-%	+ Value	- Value
Re (coil Dcr)	Ohm	6	5.00%	5.00%	6.30	5.70
Coil Mass	g	2.75				
Front Plate Thickness	mm	6	1.67%	1.67%	0.10	0.10
Front Plate Inside Diameter	mm	28.7	0.17%	0.00%	0.05	0.00
Pole Piece Diameter	mm	24.95	0.00%	0.20%	0.00	0.05
Magnet Outside Diameter	mm	100	0.50%	0.50%	0.50	0.50
Magnet Inside Diameter	mm	45	0.00%	0.00%	0.00	0.00
Magnet material Br Variance			1.00%	1.00%		
Cone Fo	Hz.	45	10.00%	10.00%	49.50	40.50
Cone +1/2 edge Mmd	g	8.6	0.00%	0.00%	8.60	8.60
Spider Deflection	mm	0.62	15.00%	15.00%	0.71	0.53
Mass for Deflection	g	100				
Qms		6.8	10.00%	10.00%	7.48	6.12
Glue Mass	g	1	2.00%	2.00%	1.02	0.98

Parameters are calculated based on the "Starting Values" and "Standard Part Specifications".

The Sealed Enclosure Predictions are calculated for the entered "Box Volume".

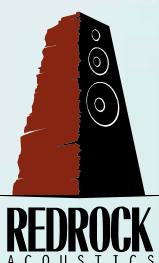
Parameters	Unit	Standard	+%	-%	+Value	-Value
Re	Ohm	6	5.0%	5.0%	6.30	5.70
Fo	Hz.	60.30	9.5%	8.3%	66.04	55.31
Qes		0.628	24.8%	17.4%	0.784	0.519
Qms		6.8	10.0%	10.0%	7.48	6.12
Qts		0.575	23.4%	16.9%	0.709	0.478
BL	Tm	7.798	2.7%	4.0%	8.01	7.49
BL^2 / Re		10.13	11.1%	12.2%	11.26	8.89
Fo/Qts		104.87	10.3%	11.2%	115.70	93.09
Mmd	g	15	1.0%	1.1%	15.16	14.84
Mms (FA)	g	16.80	0.9%	0.9%	16.96	16.64
Cms	m/N	4.15E-04	17.8%	15.8%	4.88E-04	3.49E-04
Vas	Liters	27.27	17.8%	15.8%	32.12	22.96
SPL 2.83V	dB	92.96	0.8%	0.9%	93.73	92.11
SPL 1W1m	dB	91.71	0.6%	0.7%	92.25	91.06

### Sealed Enclosure

Box Volume	Liter	10				
Qtc		1.110	16.0%	11.6%	1.288	0.981
F3	Hz.	87.82	2.5%	1.4%	90.02	86.56



Copyright Redrock Acoustics 2007



REDROCK  
ACOUSTICS

# “Simulation of T/S Parameter Production Tolerances”

## Complete set of Typical Tolerances – Better Coil

### Parameter Tolerance Worksheet

Starting Values	Unit	Value
Sd	cm <sup>2</sup>	216.42
BL	Tm	7.798
Mmd	g	15

Enter starting values and part specifications (BOLD values).

All other values are calculated.

Part Specification	Unit	Standard	+%	-%	+ Value	- Value
Re (coil Dcr)	Ohm	6	2.00%	2.00%	6.12	5.88
Coil Mass	g	2.75				
Front Plate Thickness	mm	6	1.67%	1.67%	0.10	0.10
Front Plate Inside Diameter	mm	28.7	0.17%	0.00%	0.05	0.00
Pole Piece Diameter	mm	24.95	0.00%	0.20%	0.00	0.05
Magnet Outside Diameter	mm	100	0.50%	0.50%	0.50	0.50
Magnet Inside Diameter	mm	45	0.00%	0.00%	0.00	0.00
Magnet material Br Variance			1.00%	1.00%		
Cone Fo	Hz.	45	10.00%	10.00%	49.50	40.50
Cone +1/2 edge Mmd	g	8.6	0.00%	0.00%	8.60	8.60
Spider Deflection	mm	0.62	15.00%	15.00%	0.71	0.53
Mass for Deflection	g	100				
Qms		6.8	10.00%	10.00%	7.48	6.12
Glue Mass	g	1	2.00%	2.00%	1.02	0.98

Parameters are calculated based on the "Starting Values" and "Standard Part Specifications".

The Sealed Enclosure Predictions are calculated for the entered "Box Volume".

Parameters	Unit	Standard	+%	-%	+Value	-Value
Re	Ohm	6	2.0%	2.0%	6.12	5.88
Fo	Hz.	60.30	9.2%	8.1%	65.88	55.44
Qes		0.628	20.9%	14.6%	0.760	0.536
Qms		6.8	10.0%	10.0%	7.48	6.12
Qts		0.575	19.9%	14.3%	0.689	0.493
BL	Tm	7.798	2.7%	4.0%	8.01	7.49
BL <sup>2</sup> / Re		10.13	7.7%	9.7%	10.91	9.16
Fo/Qts		104.87	7.2%	8.9%	112.45	95.54
Mmd	g	15	0.5%	0.5%	15.08	14.93
Mms (FA)	g	16.80	0.4%	0.4%	16.88	16.73
Cms	m/N	4.15E-04	17.8%	15.8%	4.88E-04	3.49E-04
Vas	Liters	27.27	17.8%	15.8%	32.12	22.96
SPL 2.83V	dB	92.96	0.5%	0.6%	93.41	92.40
SPL 1W1m	dB	91.71	0.4%	0.5%	92.07	91.23

### Sealed Enclosure

Box Volume	Liter	10				
Qtc		1.110	12.8%	8.8%	1.252	1.012
F3	Hz.	87.82	1.3%	1.0%	88.99	86.98



Copyright Redrock Acoustics 2007



# “Simulation of T/S Parameter Production Tolerances”

## Summary using Tolerance Worksheet:

Using  $Q_{ts}$ ,  $Q_{es}$  and  $V_{as}$  for QC parameters can be misleading and cause unnecessary failures.

Coil  $R_e$  has a large affect on important parameters and improving tolerance can greatly improve total speaker tolerances.

Large Changes in Cone  $F_o$  and Spider Deflection have little affect on important parameters.

# “Simulation of T/S Parameter Production Tolerances”

Performance – Based T/S Tolerance Model based on Part Tolerances

Parameter	Value	Unit	Tolerance
$R_e$	6	Ohms	+/- 2%
$F_o$	60.3	Hz.	+/- 10%
$F_o/Q_{ts}$ Ratio	105		+/- 10%
$BL^2/R_e$ Ratio	10.13		+/- 10%

These values can easily be achieved with reasonable part tolerances  
( Coil tolerances have to be improved from the +/- 5% DCR standard )

# “Simulation of T/S Parameter Production Tolerances”

**Questions, Comments?**