Evaluation of Workability/Compactability of Warm Mix Asphalt

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WMA Technical Working Group
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Acknowledgements

- Contributors
  - Karissa Mooney, NuStar
  - Gerry Reinke, MTE
  - Walaa Mogawer, UMass Dartmouth
- Rutgers Asphalt Pavement Laboratory staff

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Main Objective

- Purpose of study was to evaluate current/practical methods for evaluating workability/compactability of WMA
  - New additives/technologies coming on market every other week
  - Proper dosage rate and/or applicability to different mixtures (i.e. – asphalt rubber, high RAP, etc.)

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Preliminary Findings in NCHRP 9-43

Temp	Measure	Method	Limit
Proposed Mixing	Coating	AASHTO T195	100 %
Proposed Compaction	Compactability	Gyrations to 92 % G_{mm}	$< 0.35\ N_{design}$
Proposed Compaction Minus 30 °C	Compactability	Gyrations to 92 % G_{mm}	< 125 % Increase

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Materials

- Asphalt Binder: PG76-22 preblended with different WMA additives at different dosage rates
  - No Additive
  - Sasobit: 0.5, 1.0, and 1.5%
  - Rediset: 1.0 and 2.0%
  - 0.6% Evotherm 3G
- Asphalt Mixture: 12.5mm Superpave mixture, 4.9% AC, Trap Rock aggregate

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Compactibility/Workability Tests

- Binder Tests
  - Rotational Viscosity (current Mixing and Compaction Temperatures)
  - Casola Method (NCHRP 9-39) for Mixing and Compaction Temperatures
  - Lubricity Test (Thin-Film Rheology)
- Mixture Tests
  - University of Massachusetts Workability Device
  - Marshall Compaction
  - Gyratory Compaction

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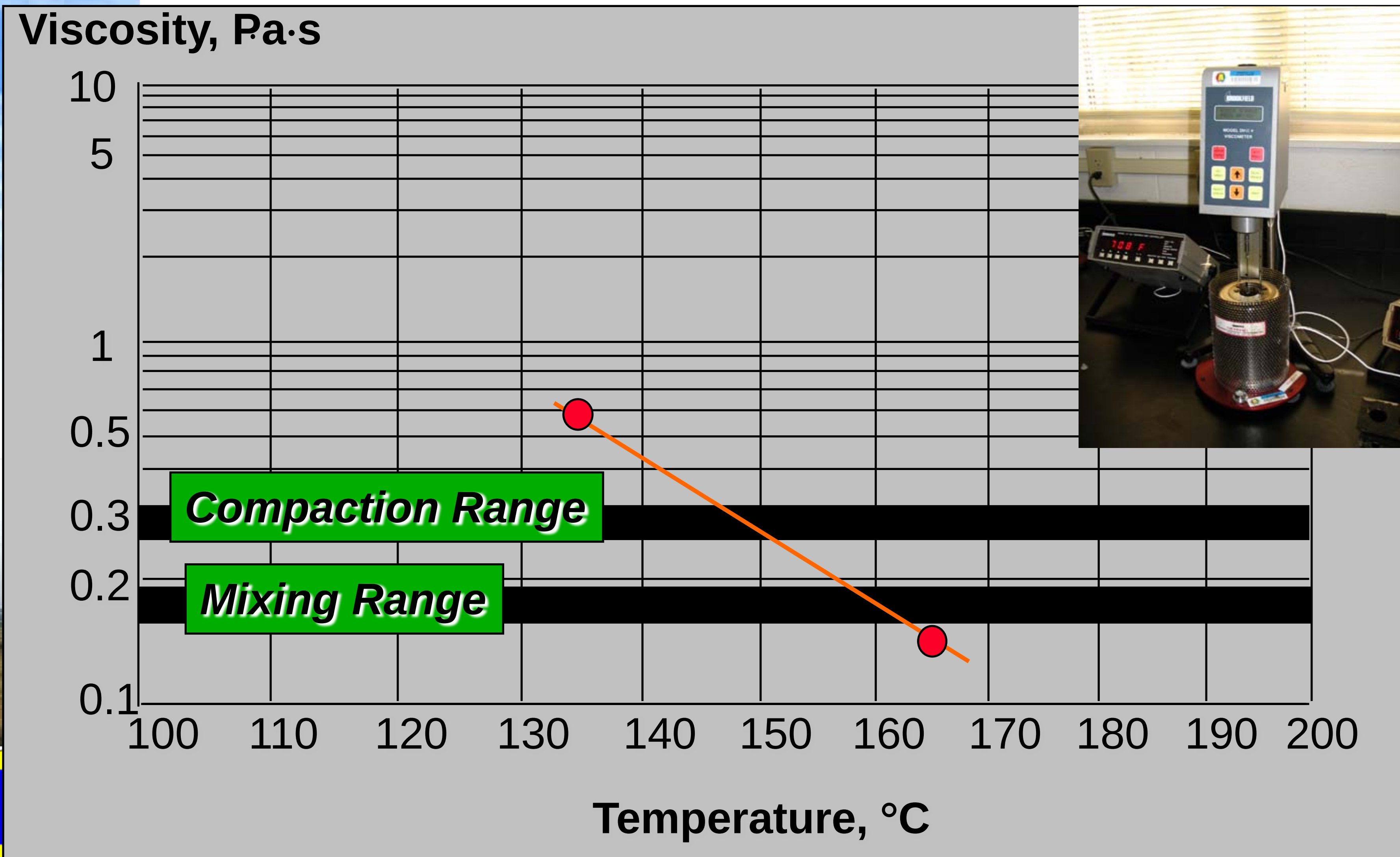
Workability/Compactibility

Binder Tests

Superpave – Mixing and Compaction Temperatures



Rotational Viscosity Results

Binder Type	Mixing Temps (F)		Compaction Temps (F)	
	High	Low	High	Low
76-22	321.0	311.5	301.1	293.4
+ 0.6% 3G	323.2	313.2	302.3	294.2
+ 0.5% Sasobit	320.9	311.4	301.1	293.4
+ 1.0% Sasobit	316.6	307.6	297.8	290.5
+ 1.5% Sasobit	336.5	324.6	311.7	302.1
+ 1.0% Rediset	317.0	307.9	298.0	290.7
+ 2.0% Rediset	313.1	304.1	294.3	287.1

Does not represent typical field compaction temperatures observed

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Casola Method – Test Procedure

- Casola Method
  - Typical DSR sample preparation
  - Frequency sweep at 3 to 5 temperatures
  - Construct Phase Angle Master Curve
  - **Determine frequency where $\delta = 86^o$**
- Calculate mixing and compaction temperatures using simple relationships established from regression models

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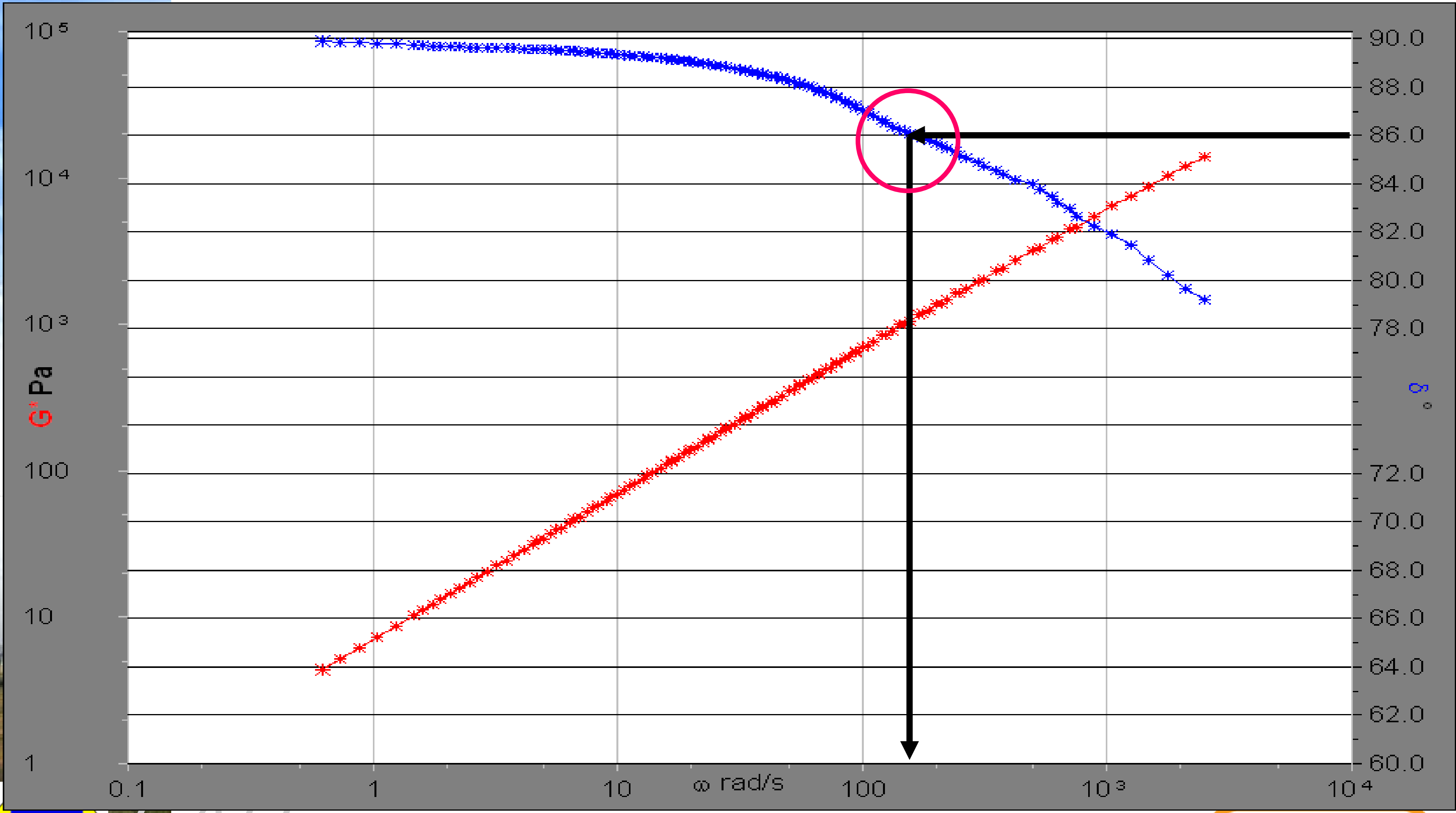
Example of Casola Method



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Freq = 158.45 Phase = 86.06 Temp = 80C

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Casola Method Calculation

- Read frequency, **ω**, at which Phase Angle hits 86 degrees
- Mixing Temperature (°F)

  $Tm = 310\omega^{-0.0135}$

- Compaction Temperature (°F)

  $Tc = 287\omega^{-0.012}$

Casola Method – Test Results

Evaluation of Warm Asphalt Technology using the Casola Method					Recommended Mixing and Compaction Temps	
					Temperature (^{o}F)	
					mix	compaction
WMA process	Sample wam-0?-08	DSR Data Collected			325	287
		temp (^{o}C)	phase (^{o})	freq (rad/sec)	-0.0135	-0.012
0.6% 3G	2	80	85.96	2.071	322	285
0.5% Saso	3	80	86.06	0.417	329	290
1.0% Saso	4	80	85.97	0.9046	325	287
1.5% Saso	5	80	86.01	0.1923	332	293
1% Rediset	6	80	86.08	1.276	324	286
2% Rediset	7	80	86.02	1.611	323	285

Does not represent typical field compaction temperatures observed

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Rotational Viscosity and Casola Method

Binder Type	Mixing Temps (°F)		Compaction Temps (°F)		Casola Method Temperatures	
	High	Low	High	Low	Mixing (°F)	Compaction (°F)
76-22	321.0	311.5	301.1	293.4	322	285
+ 0.6% 3G	323.2	313.2	302.3	294.2	322	285
+ 0.5% Sasobit	320.9	311.4	301.1	293.4	329	290
+ 1.0% Sasobit	316.6	307.6	297.8	290.5	325	287
+ 1.5% Sasobit	336.5	324.6	311.7	302.1	332	293
+ 1.0% Rediset	317.0	307.9	298.0	290.7	324	286
+ 2.0% Rediset	313.1	304.1	294.3	287.1	323	285

Recommended mixing and compaction temperatures are unrealistically high when compared to observations of warm mix projects

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Thin-Film Rheology

- Rheology of materials in thin films are different than bulk rheology
  - **Typical DSR uses a 1000 μ film**
  - **Mineral fines are smaller than 50 μ**
  - **MTE began testing at 100 μ and are now working at 25μ**
  - MTE's investigations began by looking at tribology testing conducted by the lubricating and medical prosthetics industries and investigations performed by people studying rheology of platetectonics

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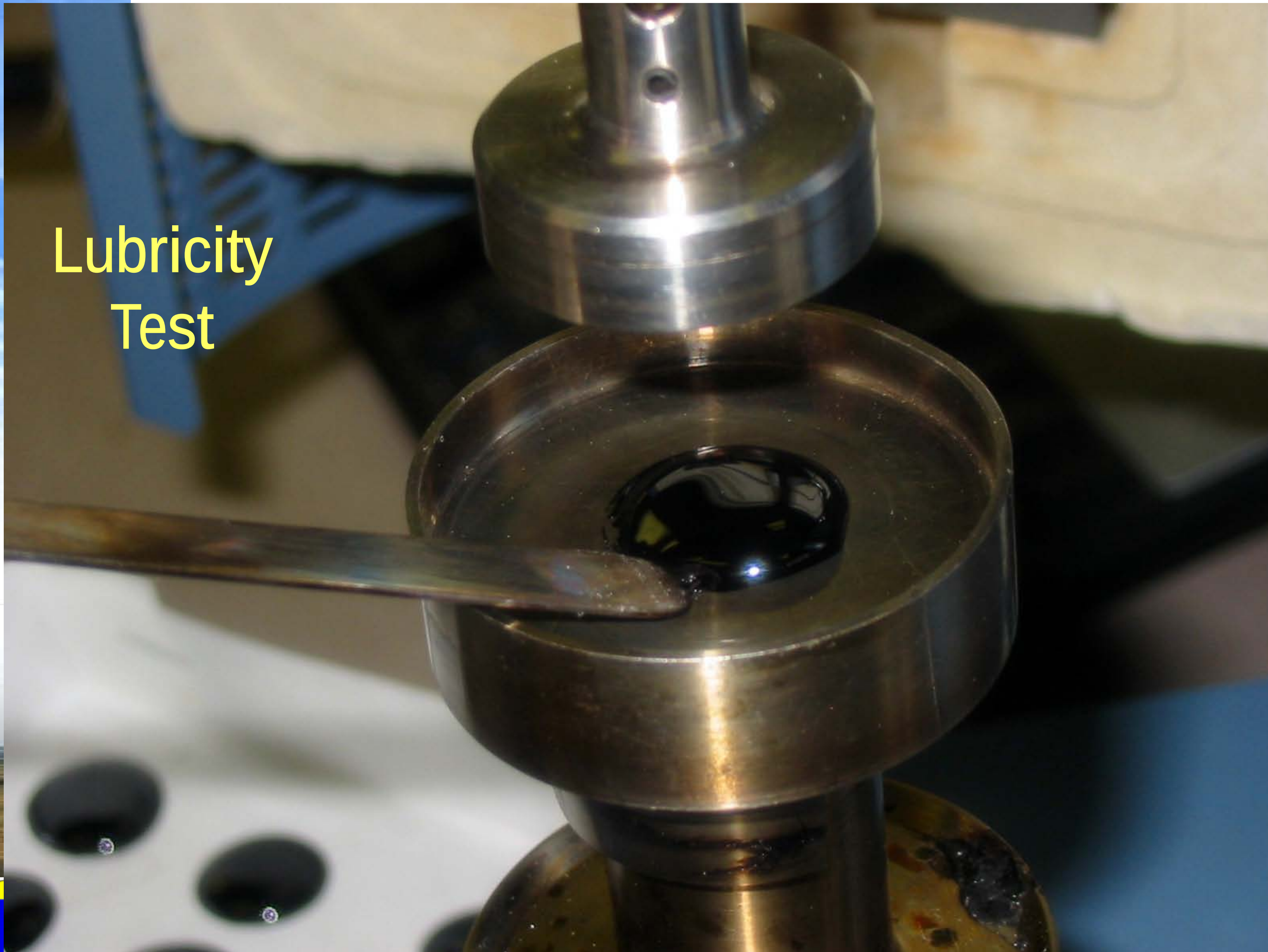
Lubricity Test



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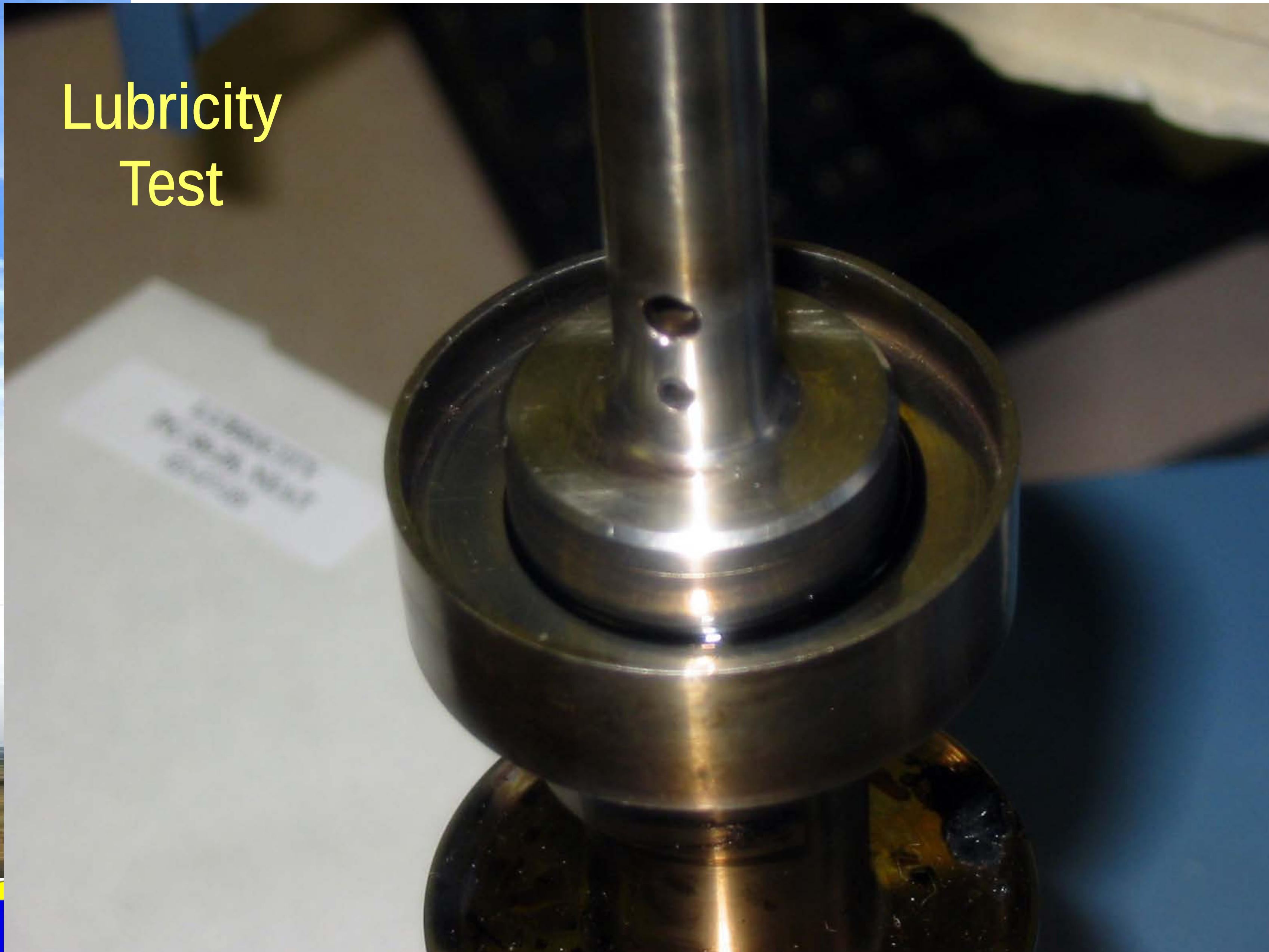
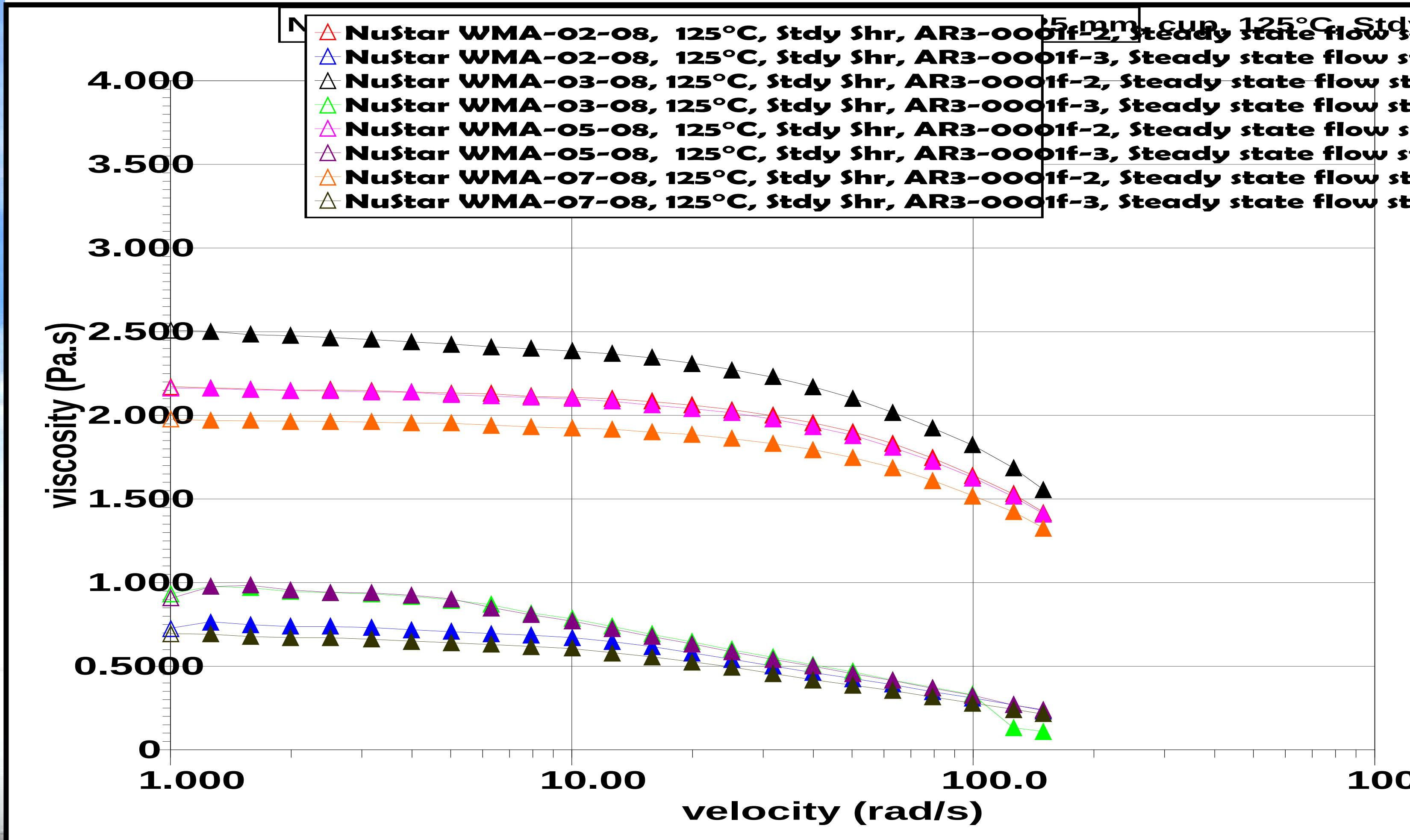
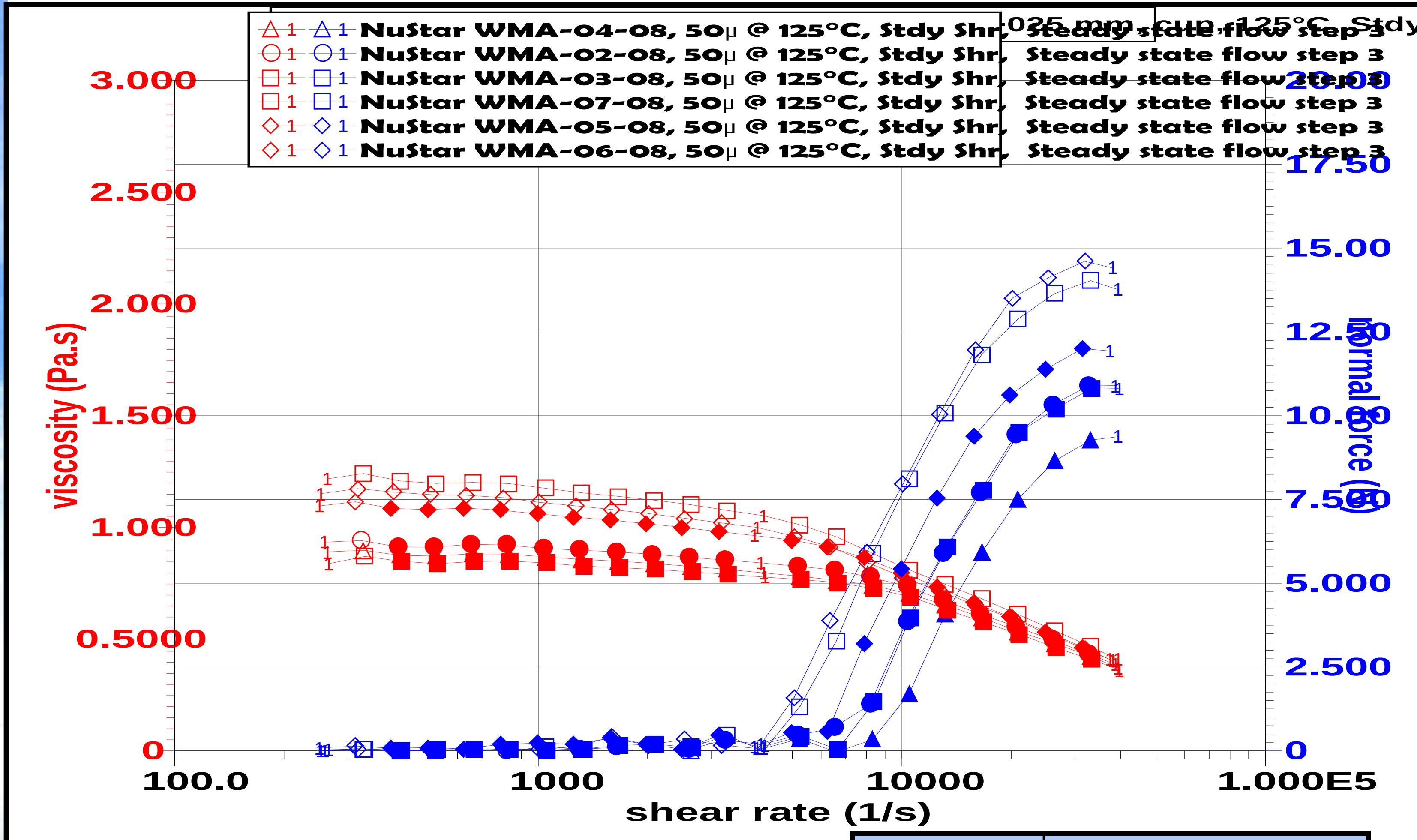
Lubricity Test





CODE	FORMULATION	CODE	FORMULATION
WMA-02-08	0.6% EVOTHERM 3G	WMA-05-08	1.5% SASOBIT
WMA-03-08	0.5% SASOBIT	WMA-06-08	1.0% REDISET
WMA-04-08	1.0% SASOBIT	WMA-07-08	2.0% REDISET

The point to be made is that as the gap gets smaller the apparent viscosity decreases for the same rotational velocity



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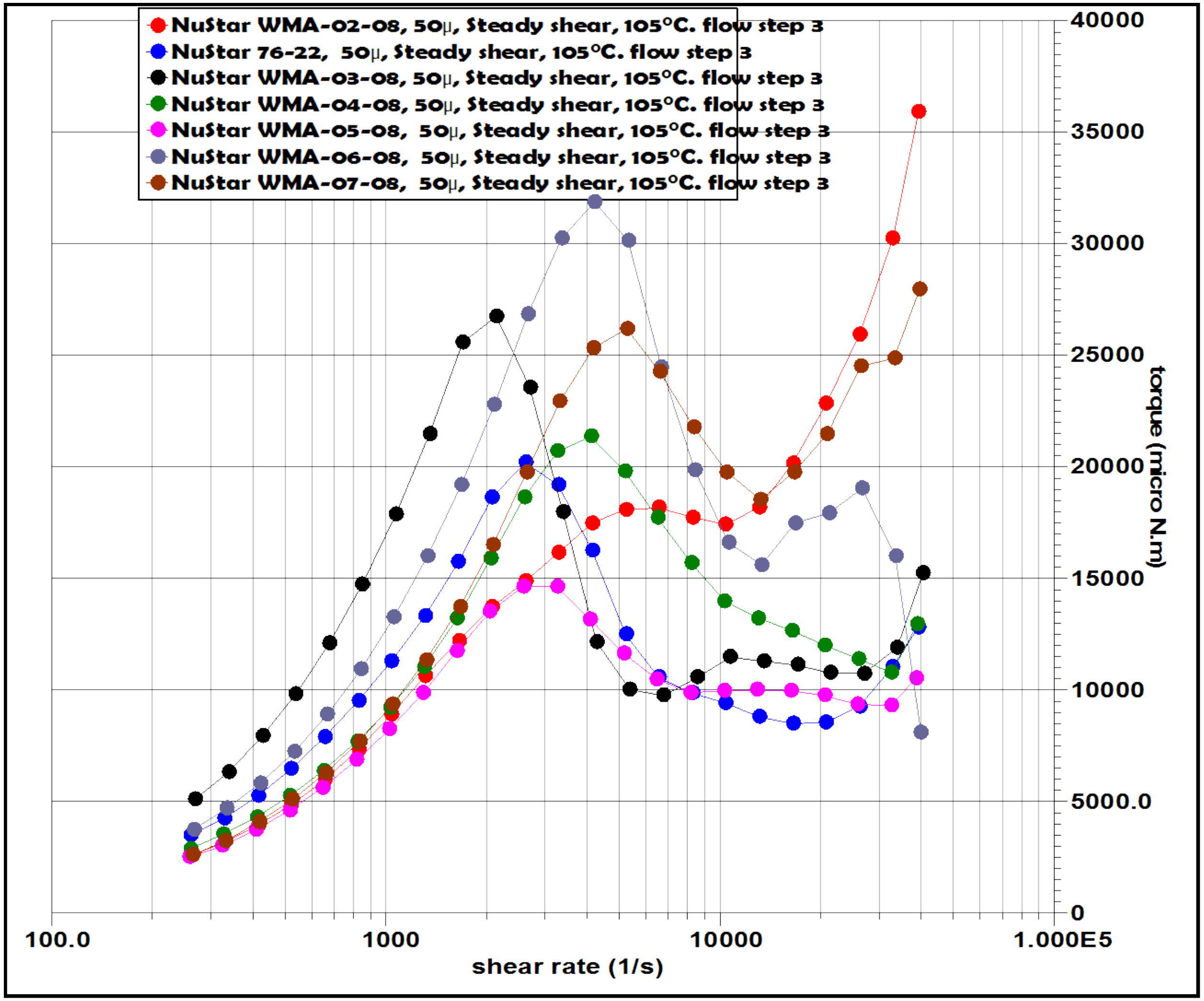
CODE	FORMULATION
WMA-04-08	1.0% SASOBIT
WMA-07-08	2.0% REDISET
WMA-02-08	0.6% EVOTHERM 3G
WMA-06-08	1.0% REDISET
WMA-03-08	0.5% SASOBIT
WMA-05-08	1.5% SASOBIT

Shear Rate vs Applied Torque



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Greater the shear rate that can be sustained before peak is achieved the more workable the mixture should be.

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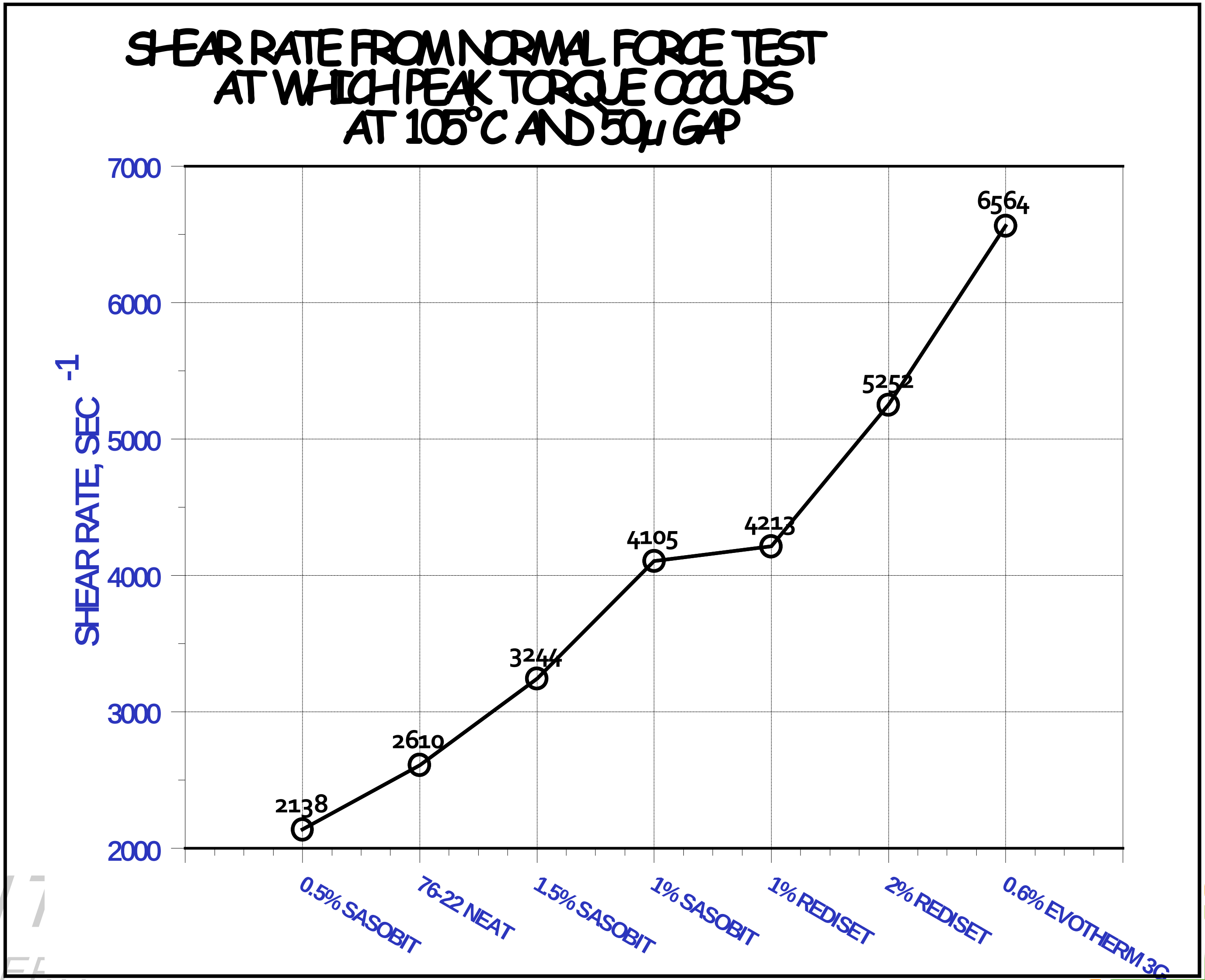
Final Thin-Film Rheology Rankings



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Asphalt Binder Test Workability Rankings

	Rotational Vis	Casola	Lubricity
Best	2% Rediset	PG76-22	0.6% 3G
	1% Sasobit	0.6% 3G	2% Rediset
	1% Rediset	2% Rediset	1% Rediset
	0.5% Sasobit	1% Rediset	1.5% Sasobit
	PG76-22	1% Sasobit	1% Sasobit
	1.5% Sasobit	0.5% Sasobit	PG76-22
Worst	0.6% 3G	1.5% Sasobit	0.5% Sasobit

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Workability/Compactibility

Mixture Tests

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UMass Workability Mixer

- Continually measures temperature and torque on mixing blade
  - Torque is the unit representing workability (i.e. – higher torque values, poorer workability)
  - Device essentially measures resistance of loose mix to move/flow
  - Method generally assumed to be “baseline” for comparisons

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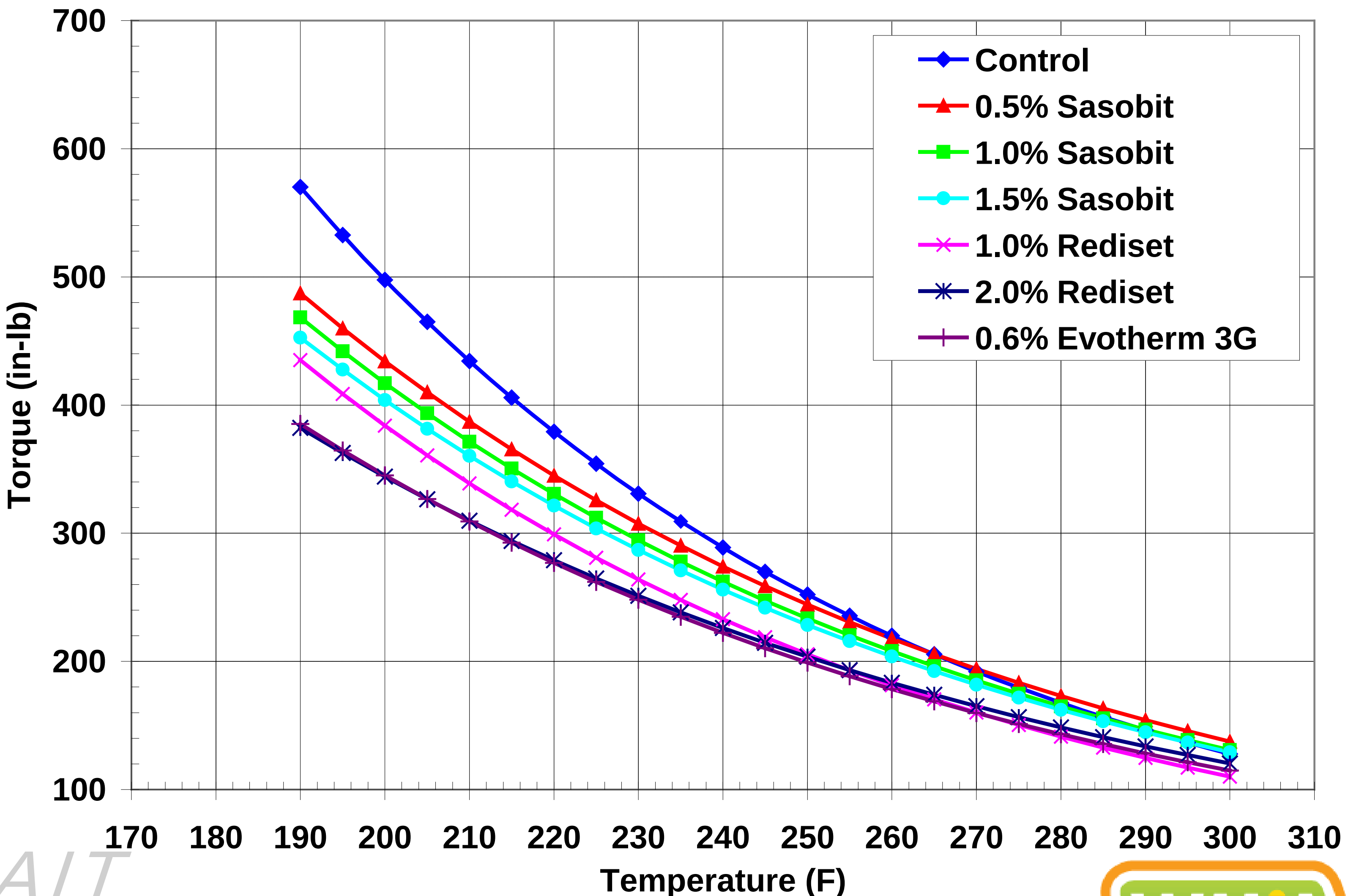
Workability – Starting at 320ºF



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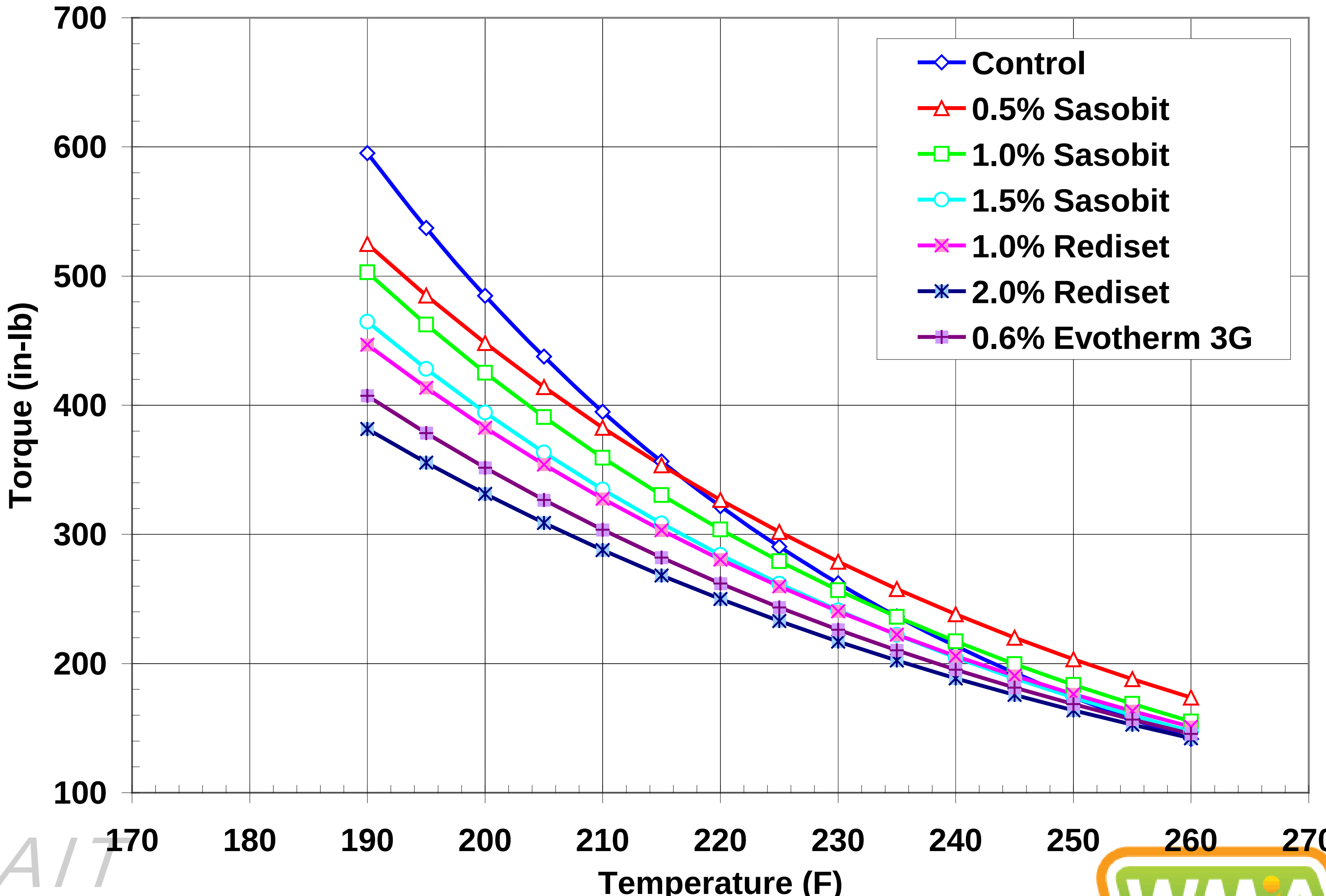
Workability – Starting at 270^{o}F



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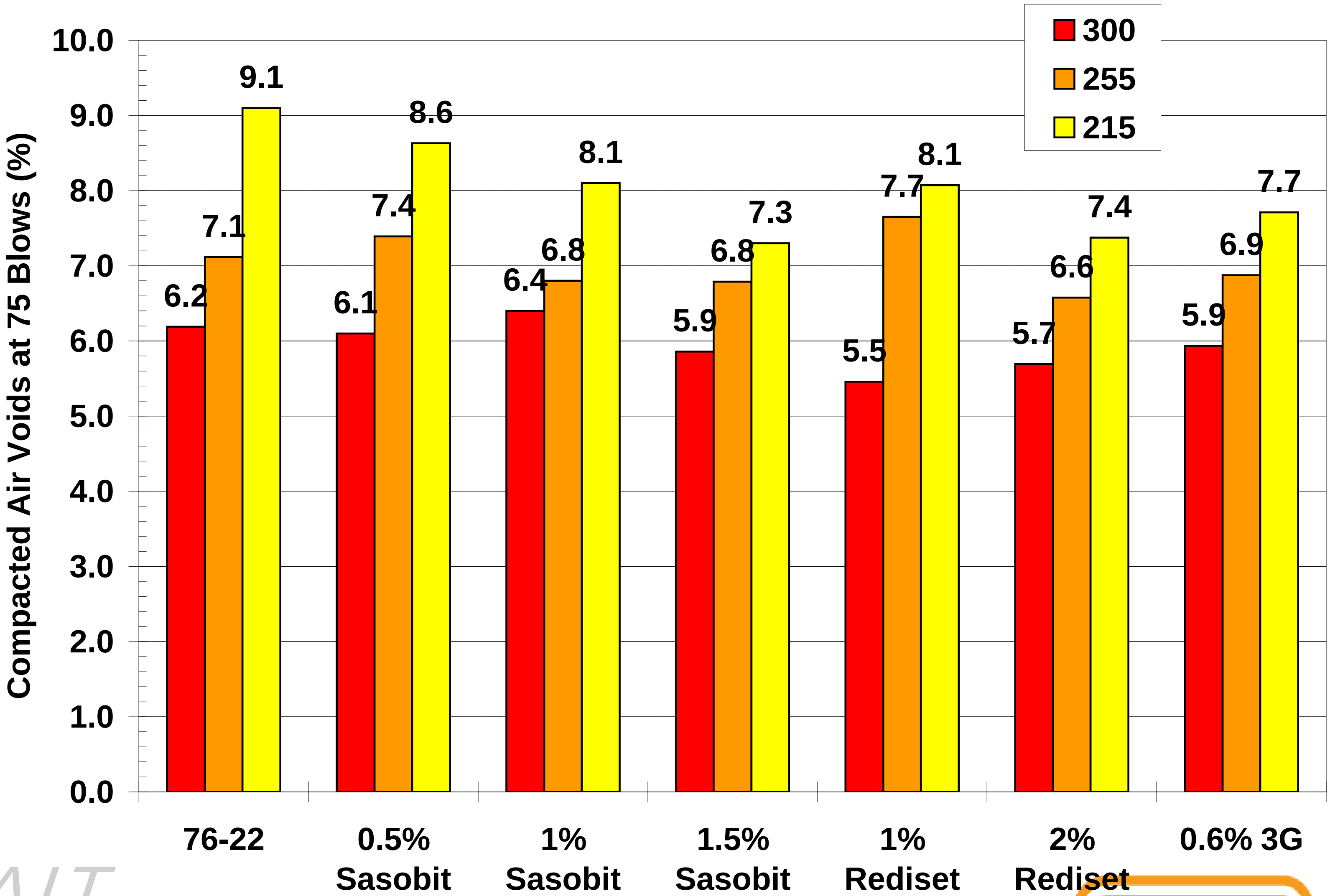
Marshall Compactor

- Historically, the Marshall Compactor has been known to be sensitive to mixture temperature
- Therefore, if HMA becomes less workability due to cooling (or temperature changes) perhaps it can be used to assess general workability/compactibility of WMA

Marshall Compaction Procedure

- Mix HMA samples at
  - 315F, 270F, and 230F
- Cure for 2 hours and compact loose mix at 15F lower than mixing temperature
  - 300F, 255F, and 215F
- Measure air voids of compacted samples
- Construct trendline (exponential fit) of compacted air voids vs compaction temperature

Marshall Compacted Air Voids



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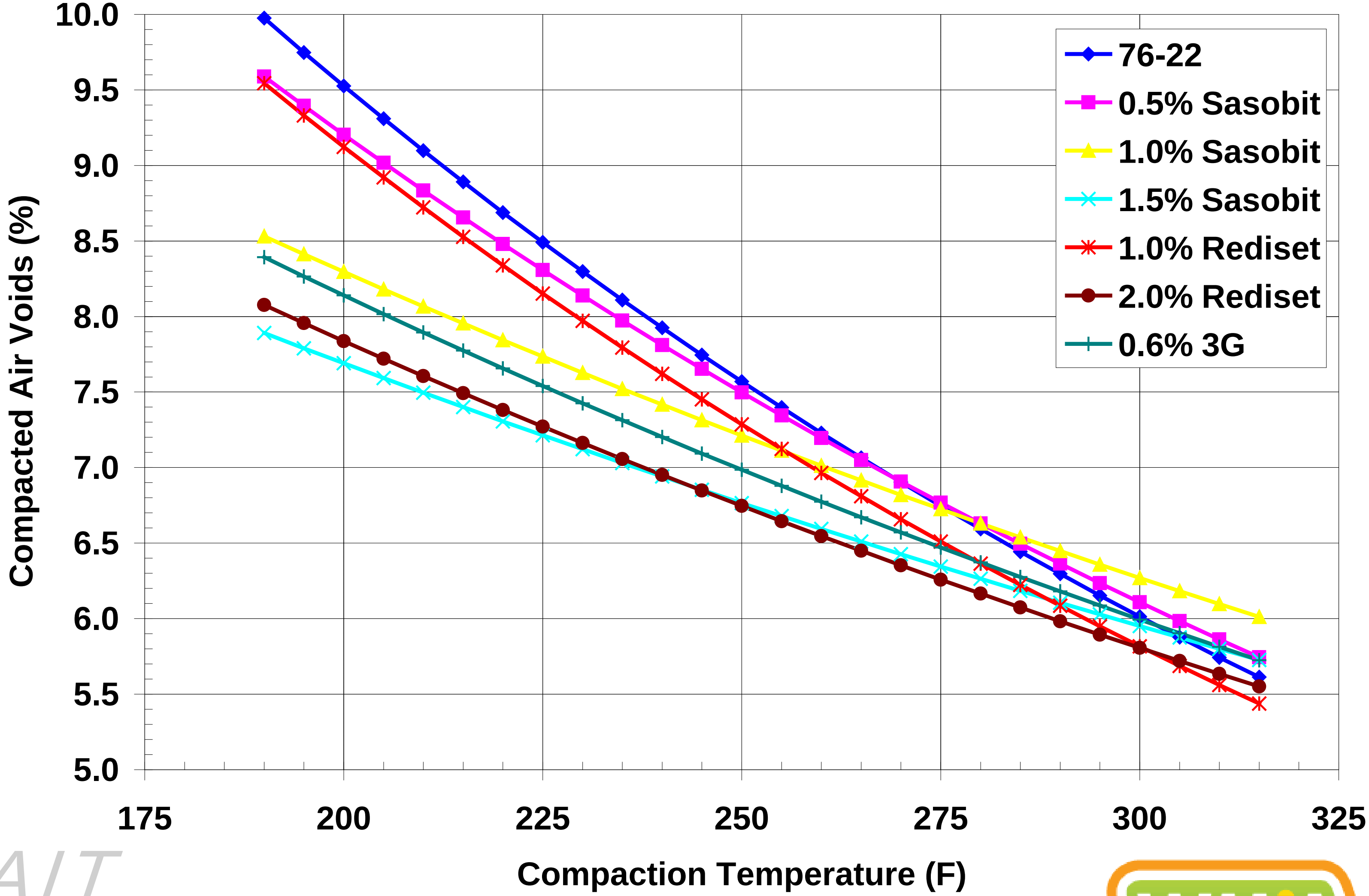
Marshall Compactibility Trends



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Gyratory Compactor

- Known to be generally insensitive to compaction temperatures (at least in typical range)
- Looked at:
  - NCHRP 9-43: Gyrations to 92% of G_{mm}
  - Compacted density at 100 gyrations
  - Compaction rate (mm/gyration) to achieve predetermined density (7% air voids)
- Same sample prep/conditions used as in Marshall compaction

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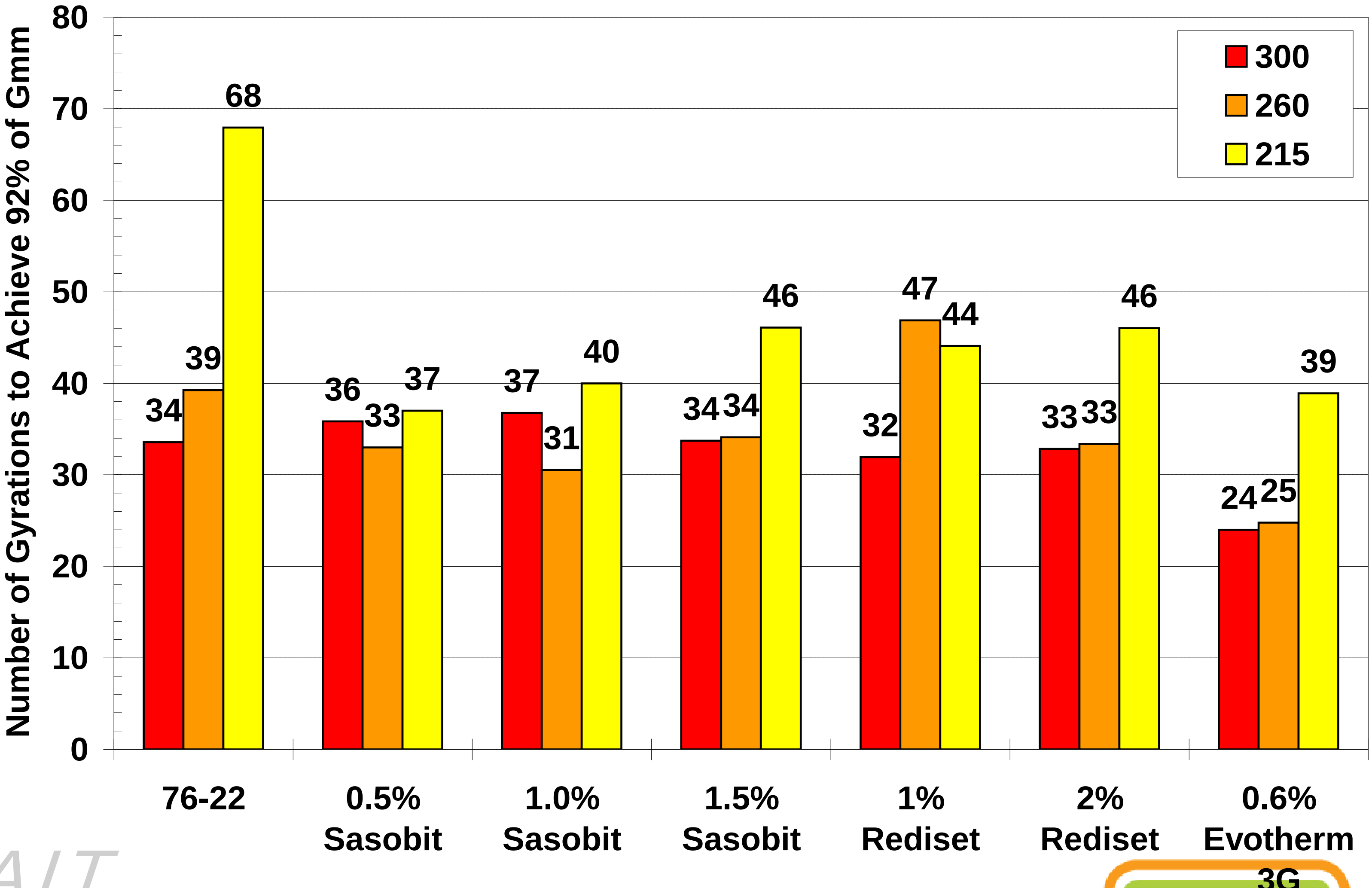
Gyrations to 92% of G_{mm}



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Gyrations to 92% of G_{mm}

Proposed Compaction	Compactability	Gyrations to 92 % G_{mm}	< 0.35 N_{design}

Proposed Compaction Temperature, 149C (˜ 300F)	76-22	0.5% Sasobit	1.0% Sasobit	1.5% Sasobit	1% Rediset	2% Rediset	0.6% Evotherm
	0.34	0.36	0.37	0.34	0.32	0.33	0.24

Proposed Compaction Minus 30 °C	Compactability	Gyrations to 92 % G_{mm}	< 125 % Increase

Compaction Temperature - 26C (˜ 260F)	76-22	0.5% Sasobit	1.0% Sasobit	1.5% Sasobit	1% Rediset	2% Rediset	0.6% Evotherm
	117	98	91	102	140	99	74

Compaction Temperature - 48C (˜ 215F)	76-22	0.5% Sasobit	1.0% Sasobit	1.5% Sasobit	1% Rediset	2% Rediset	0.6% Evotherm
	202	110	119	137	131	137	116

Based on Compaction Results of PG76-22

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Gyrations to 92% of G_{mm}

Proposed Compaction Minus 30 °C	Compactability	Gyrations to 92 % G_{mm}	< 125 % Increase

Compaction Temperature - 26C (˜ 260F)	76-22	0.5% Sasobit	1.0% Sasobit	1.5% Sasobit	1% Rediset	2% Rediset	0.6% Evotherm
	117	92	83	101	147	102	103

Compaction Temperature - 48C (˜ 215F)	76-22	0.5% Sasobit	1.0% Sasobit	1.5% Sasobit	1% Rediset	2% Rediset	0.6% Evotherm
	202	103	109	137	138	140	162

Based on the respective asphalt binder

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Gyrations to 92% of G_{mm}

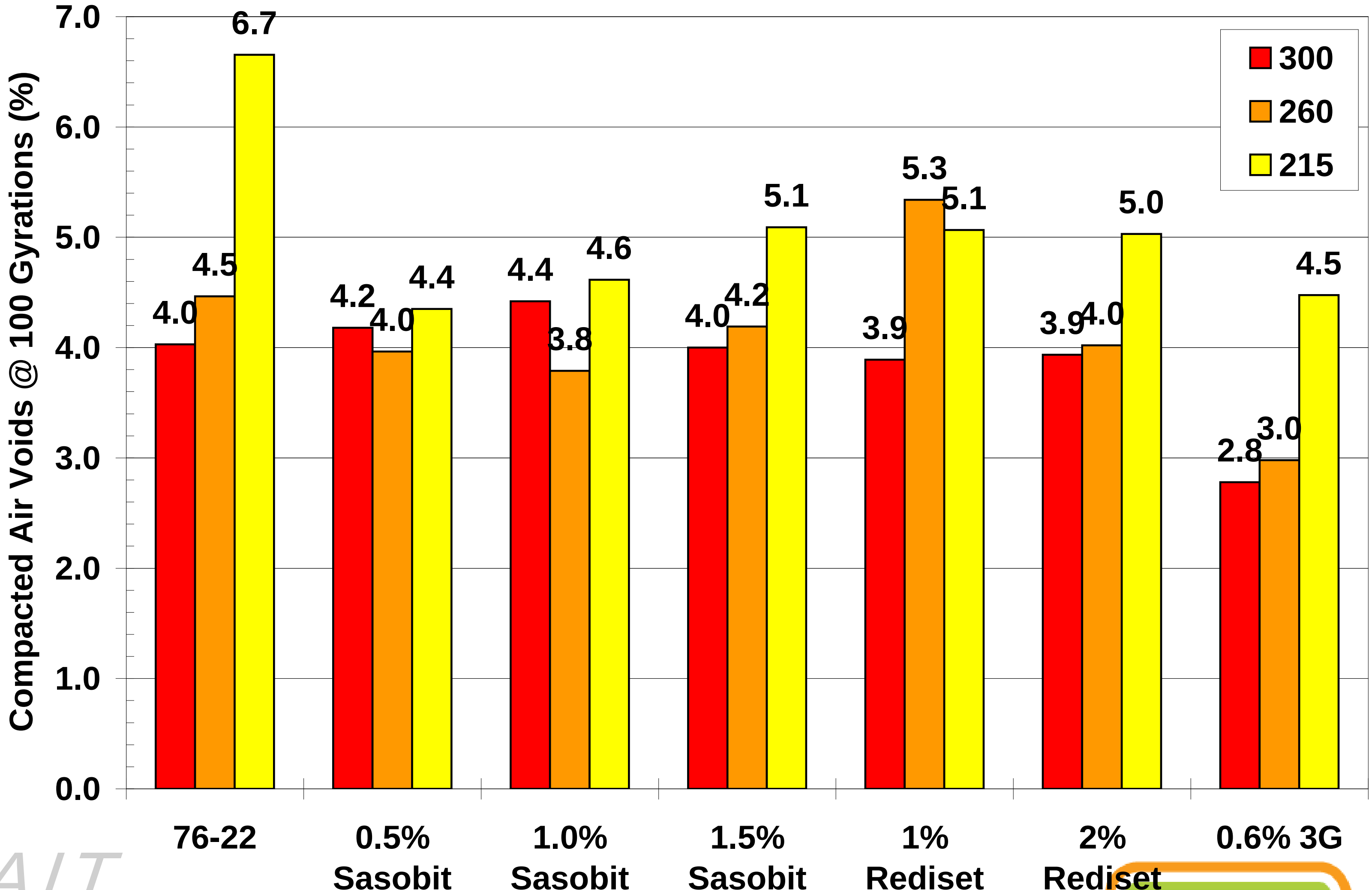
Best ↑ … ↓ Worst

Preliminary NCHRP 9-43 (Based on PG76-22)		
< 0.35 N_{design}	<125% (-26C)	<125% (-48C)
0.6% Evotherm 3G	0.6% Evotherm 3G	0.5% Sasobit
1% Rediset	1.0% Sasobit	0.6% Evotherm 3G
2% Rediset	0.5% Sasobit	1.0% Sasobit
1.5% Sasobit	2% Rediset	1% Rediset
76-22	1.5% Sasobit	2% Rediset
1.0% Sasobit	76-22	1.5% Sasobit
0.5% Sasobit	1% Rediset	76-22

Best ↑ … ↓ Worst

Preliminary NCHRP 9-43 (Based on Respective Binder)		
< 0.35 N_{design}	<125% (-26C)	<125% (-48C)
0.6% Evotherm 3G	1.0% Sasobit	0.5% Sasobit
1% Rediset	0.5% Sasobit	1.0% Sasobit
2% Rediset	1.5% Sasobit	1.5% Sasobit
1.5% Sasobit	2% Rediset	1% Rediset
76-22	0.6% Evotherm 3G	2% Rediset
1.0% Sasobit	76-22	0.6% Evotherm 3G
0.5% Sasobit	1% Rediset	76-22

Compacted Density at 100 Gyrations



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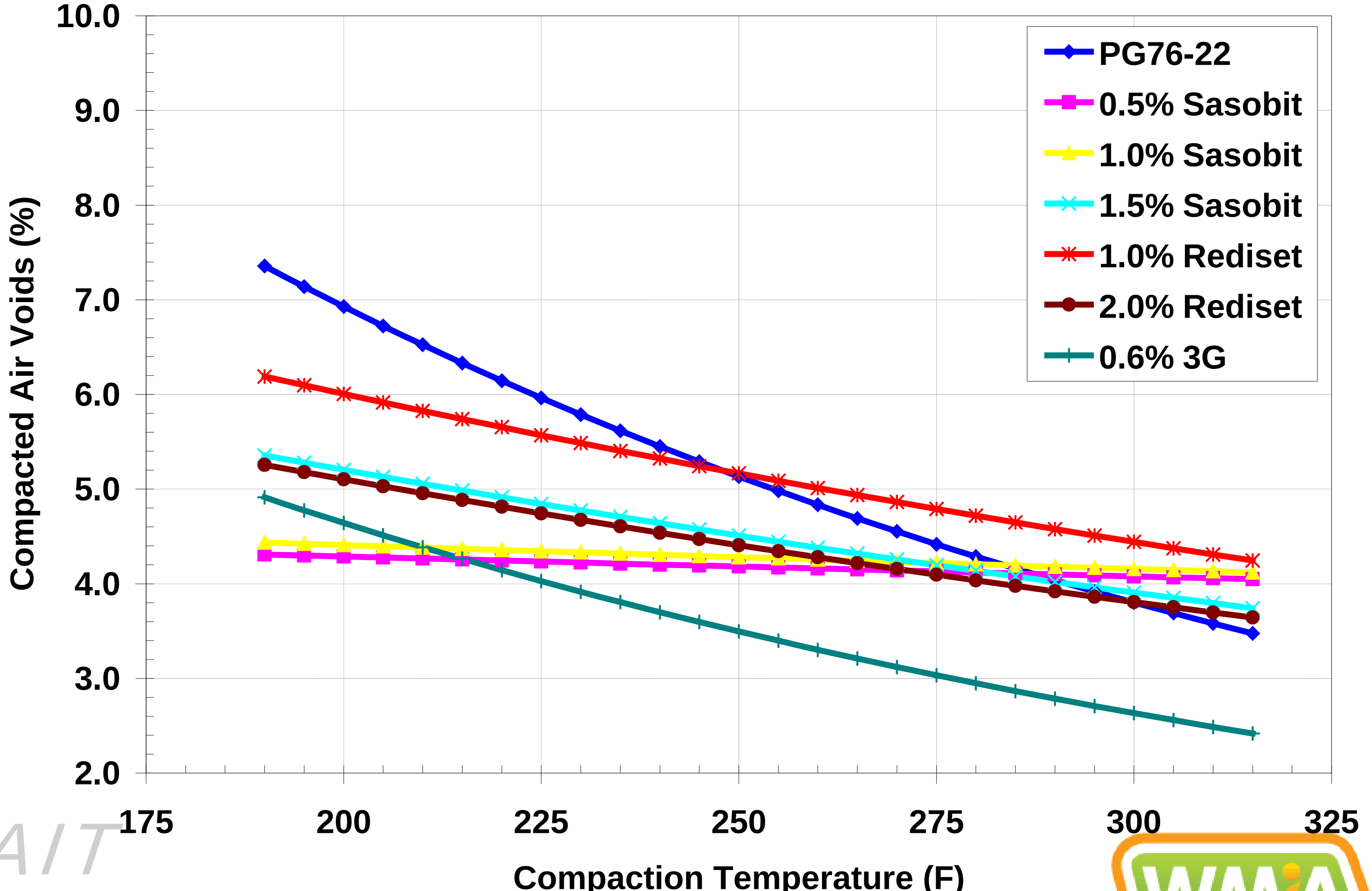
Gyratory Compactability Trends



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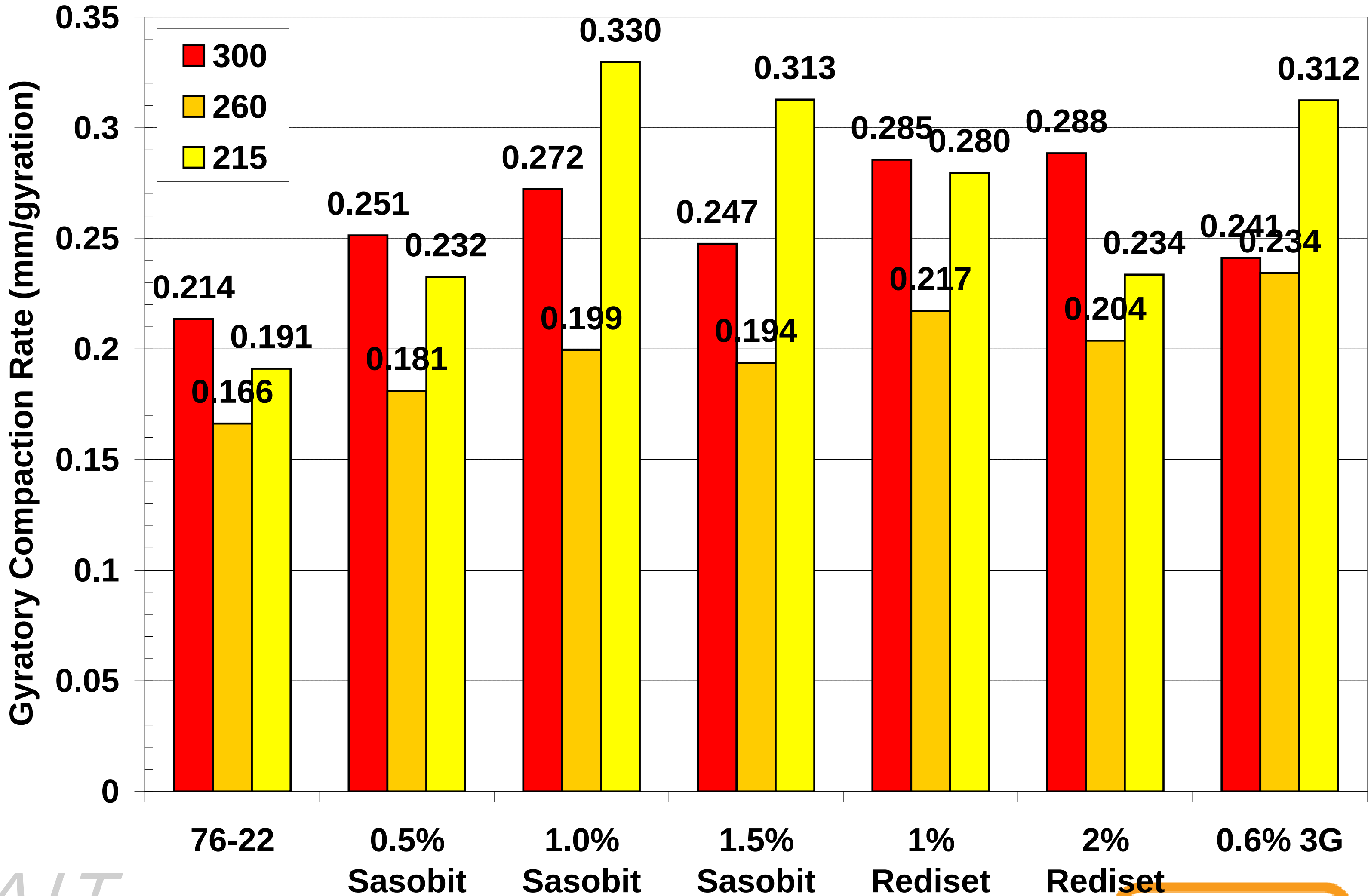
Gyratory Compaction Rate



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Compacted to predetermined density of 7% air voids (+/- 0.2%)

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Final Rankings

Binder Type	Rotational Viscosity	Casola Method	Lubricity Test @ 221°F
PG76-22	5	1	6
0.6% Evotherm 3G	6	1	1
0.5% Sasobit	4	5	7
1.0% Sasobit	2	4	5
1.5% Sasobit	7	6	4
1.0% Rediset	3	3	3
2.0% Rediset	1	2	2

Binder Type	Asphalt Workability Device @ 215°F	Marshall Compactor @ 215°F	NCHRP 9-43 <125% (Compact Temp -26C)	NCHRP 9-43 <125% (Compact Temp -48C)	NCHRP 9-43 <125% (Compact Temp -26C)	NCHRP 9-43 <125% (Compact Temp -48C)
PG76-22	7	7	6	7	6	7
0.6% Evotherm 3G	2	3	1	2	5	6
0.5% Sasobit	6	6	3	1	2	1
1.0% Sasobit	5	4	2	3	1	2
1.5% Sasobit	4	1	5	6	3	3
1.0% Rediset	3	5	7	4	7	4
2.0% Rediset	1	2	4	5	4	5

Based on PG76-22

Based on Respective Binder

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Conclusions

- Conventional mixing and compaction temperature assessment does not seem to correspond to field observations
- Gyratory compactor was generally insensitive to compaction temperature when compared to Marshall
- Lubricity Test (binders), UMass Workability and Marshall Compaction showed comparable ranking
  - NCHRP 9-43 <125% @215F close, but some discrepancies

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Conclusions (continued)

- Testing indicated that additives preblended in asphalt binder could be screened using Lubricity test
  - Future work required on criteria
  - Can be used to currently compare additives and/or dosage rate
- Field assessment (plant or laboratory mixture production) could be evaluated using the Marshall compactor, Bucket-mixer type device, and NCHRP 9-43 @ 215°F

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Thank you for your time!

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