

Competing Technologies

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What is MUSIC

- un-throttled, lean burn combustion
- 20% reduction in fuel consumption & CO₂
- Needs no new support technology
- Speed & load variation by injection control
- Significant reductions in NOx
- Reductions in HC

Competing Technologies

- Diesel
- gdi (wall and spray guided)
- HCCI/CAI

Diesel

- Un-throttled lean burn engine
- Good fuel economy
- NOx issues
- Particulate issues
- Cost differential
- Injection pressures of 2,000bar
- Refinement and isolation

gdi

- First generation wall guided disappointing
- Second generation spray guided more promising
- Piezo injectors at 200bar
- Cannot run ultra lean
- Injector targeting and stratification difficult
- Fuel must be delivered late in the cycle

MUSIC vs Existing Technology

Engine	Power	MPG			CO2 g/km		Benefit			CO2 g/km
		Urban	Extra Urban	Combined			Urban	Extra Urban	Combined	
1.8lt Gasoline – PFI	125 ps	25.7	50.5	37.2	182					
1.8lt gdi Gasoline (wall guided)	130 ps	28.5	49.6	39.2	173	11%	-2%	5%	-5%	
2.0lt Turbo Diesel	130 ps	34.9	58.9	47.1	159	22%	19%	20%	-8%	
2.0lt Gasoline – PFI	145 ps	25.2	47.1	35.8	189					
2.0lt MUSIC	137 ps	31.0	55.6	42.9	151	23%	18%	20%	-20%	

All data from manufacturers website

Conventional Engine Comparison

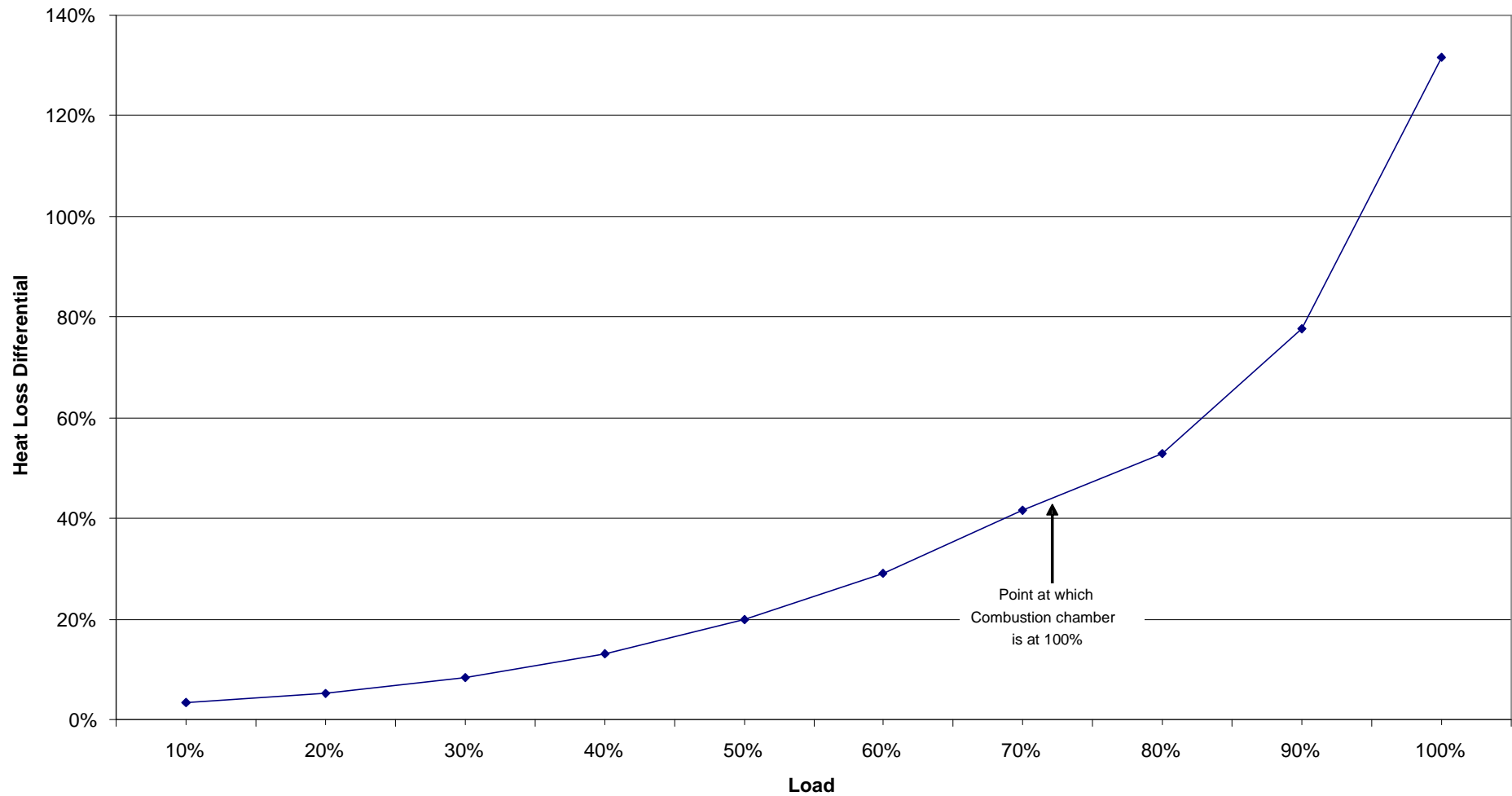
	MUSIC			
	Comb. Chamber	Area above piston	Total Volume	SIGE Conventional
Stroke	83mm			83mm
CR	11.5			11.5
Amb Temp	293K			293K
% stroke	0			0
Piston disp	0			8.2mm
diameter	30mm	87.5mm		87.5mm
Length	50mm	2.3mm		8.2mm
Area end face	707mm ²	6013mm ²		6013mm ²
Vol	35343mm ³	13744mm ³	49087mm ³	49087mm ³
Area cylinder	4712mm ²	628mm ²		2244mm ²
Total Area	6126mm ²	12655mm ²	18781mm ³	14270mm ³

Combustion Temperatures

- Combustion temperature = 2100K
- Compression temperature = 778k

Engine Load	% Chamber	Temp in chamber K	Main Cyl K	Music Heat Loss	SIGE Heat Loss	MUSIC as % of SIGE
10%	14%	962	778	9.5E+15	2.8E+17	3.4%
20%	28%	1145	778	1.5E+16	2.8E+17	5.3%
30%	42%	1329	778	2.3E+16	2.8E+17	8.4%
40%	56%	1513	778	3.6E+16	2.8E+17	13.1%
50%	69%	1696	778	5.5E+16	2.8E+17	19.8%
60%	83%	1880	778	8.1E+16	2.8E+17	29.1%
70%	97%	2063	778	1.2E+17	2.8E+17	41.6%
80%	111%	2100	1214	1.5E+17	2.8E+17	52.8%
90%	125%	2100	1664	2.2E+17	2.8E+17	77.8%
100%	139%	2100	2100	3.6E+17	2.8E+17	131.6%

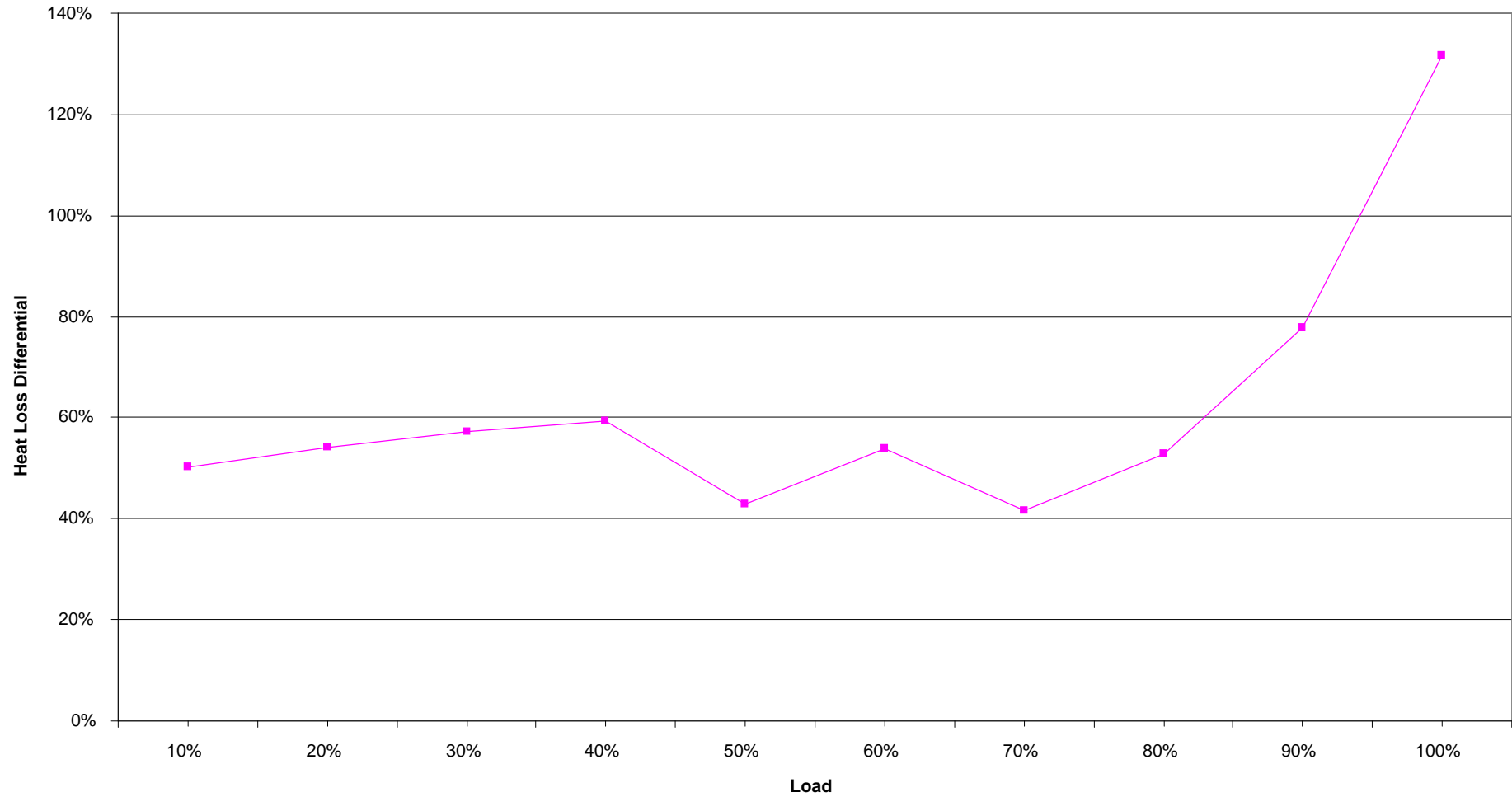
MUSIC Radiated Heat Loss as % of Conventional Engine



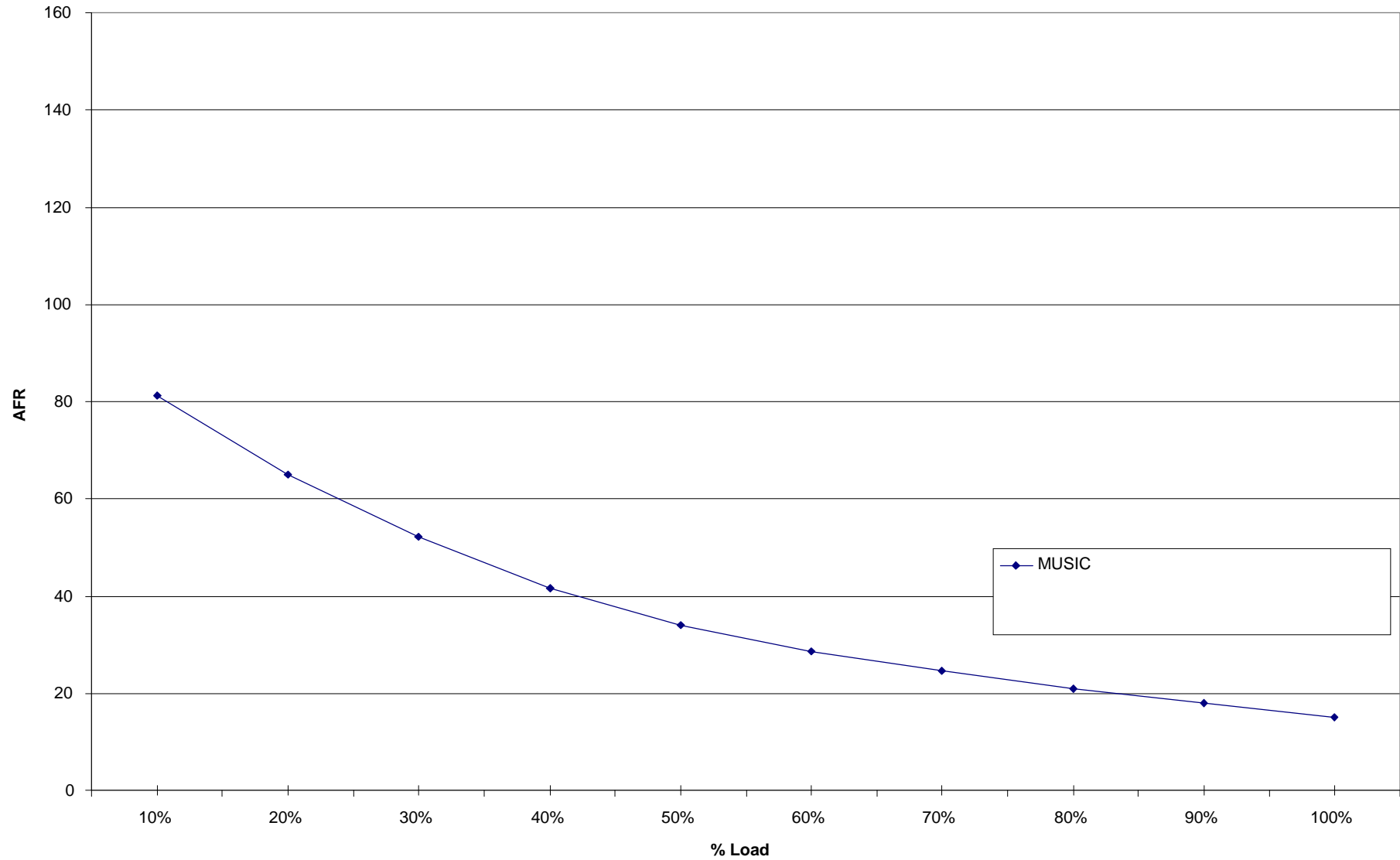
Spray Guided gdi Comparison

- Based on published BMW data
- BMW engine has 3 distinct operating regimes
- Very lean, stratified, for light load supposedly unthrottled
- Lean stratification for mid load with throttling
- Stoichiometric for full load

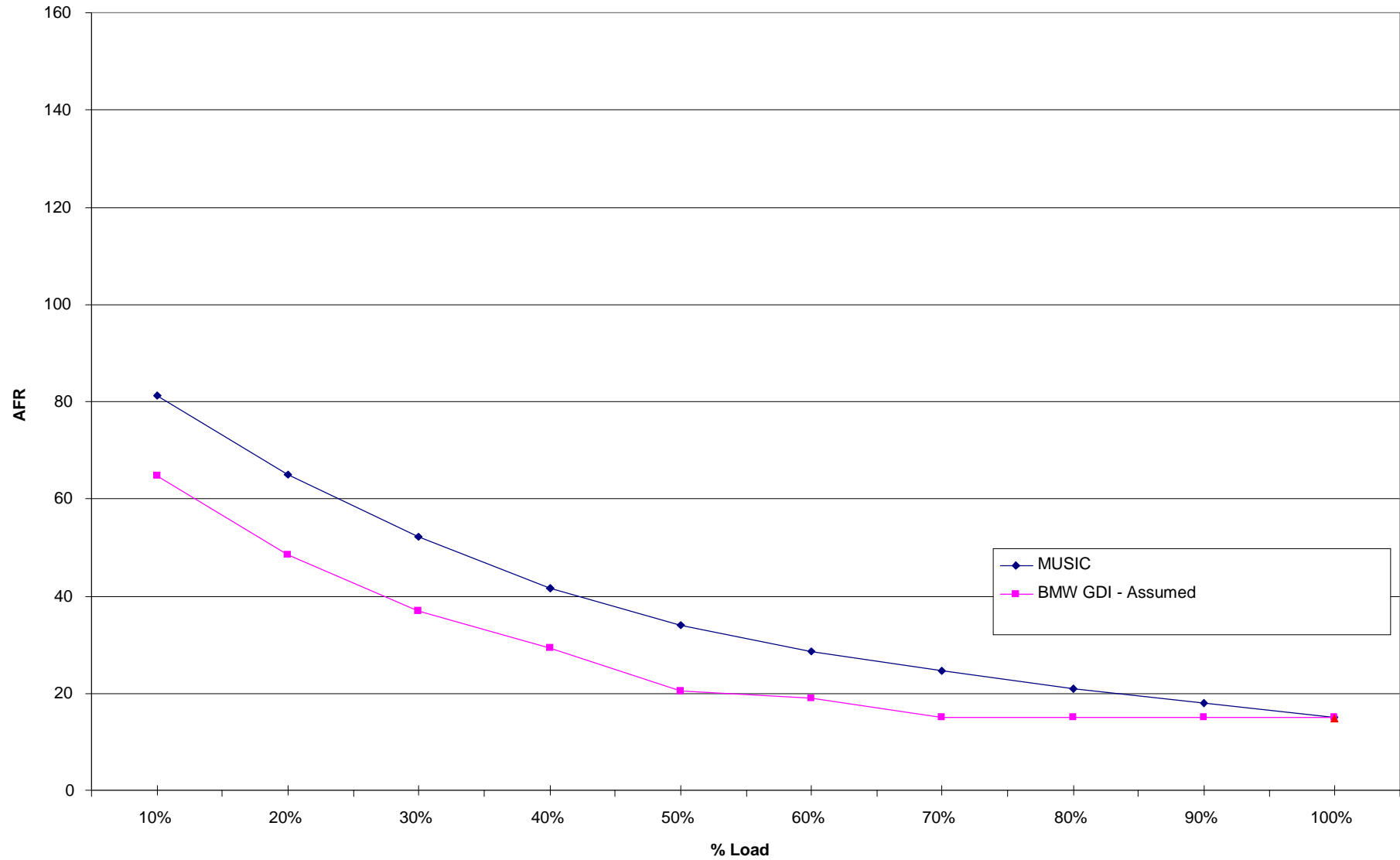
MUSIC Radiated Heat Loss as % of Spray Guided gdi Engine



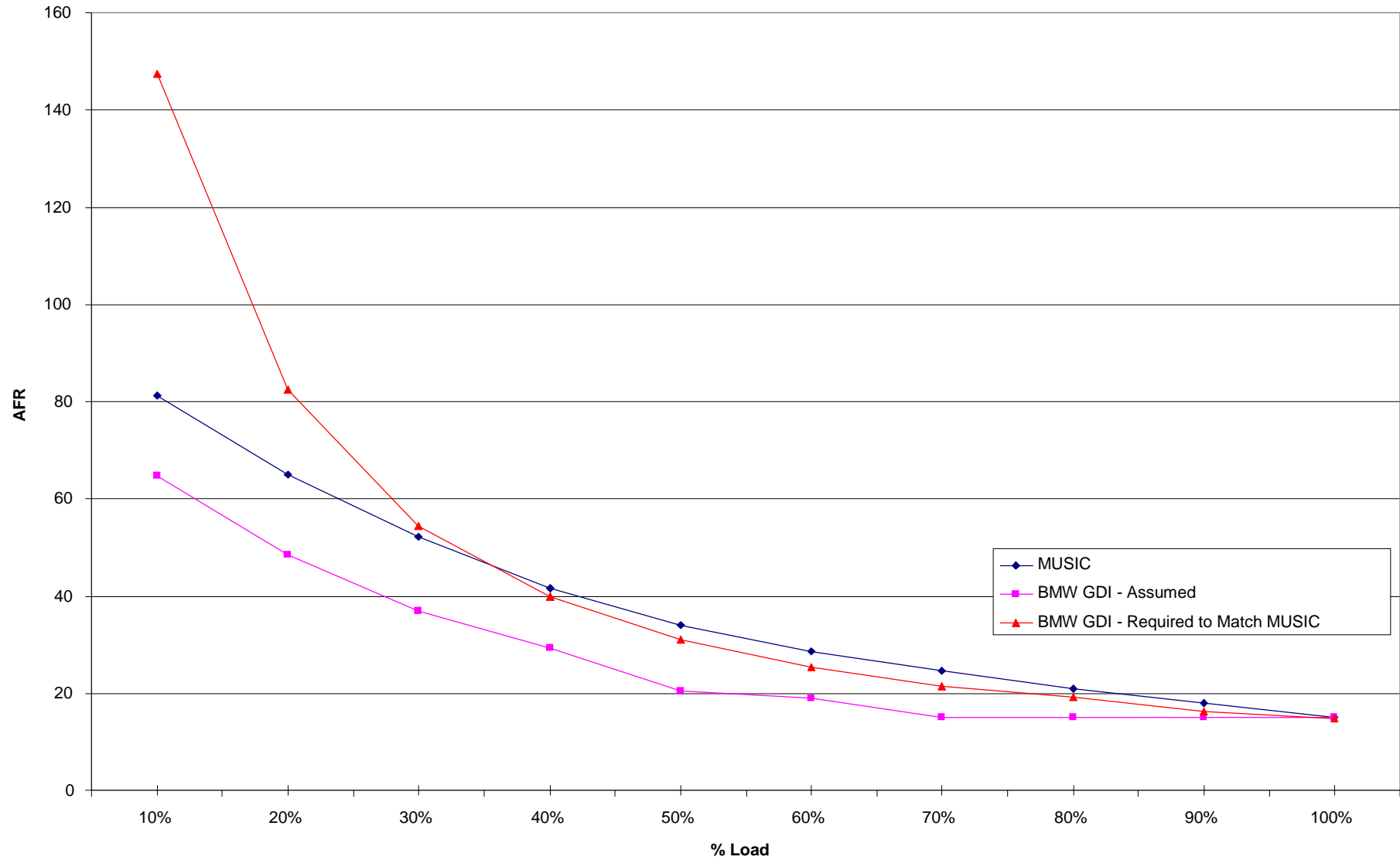
Comparison of Air Fuel Ratios



Comparison of Air Fuel Ratios



Comparison of Air Fuel Ratios



HCCI/CAI

- Future technology
- Operates over limited speed & load range
 - Needs to switch in and out of mode
 - Transient issues
 - Structural and NVH issues
- Requires considerable new support technology
 - Complex EGR control
 - Variable compression
 - Inlet air heating
 - Not a cheap or simple solution
- Claims of 15% improvement over PFI (GM Oct 07)
- 5% LESS than MUSIC

Conclusion

- MUSIC out performs all competing technology
 - Emissions
 - Economy
 - Cost
- MUSIC needs no new support technology
- MUSIC offers other secondary benefits