Hybrid Bus Particulate Trap Field Test
NYC, winter 2001

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Outline

- NYC field test
- Regeneration requirements
- Uncontrolled regeneration
- Conclusions
- Design improvements
- Acknowledgements

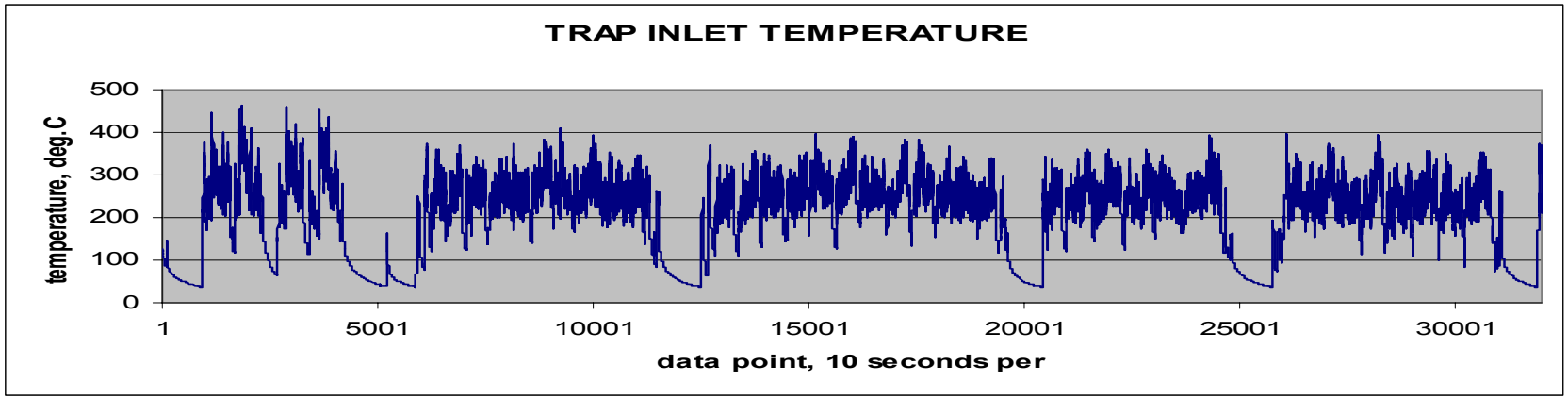
NYC field test

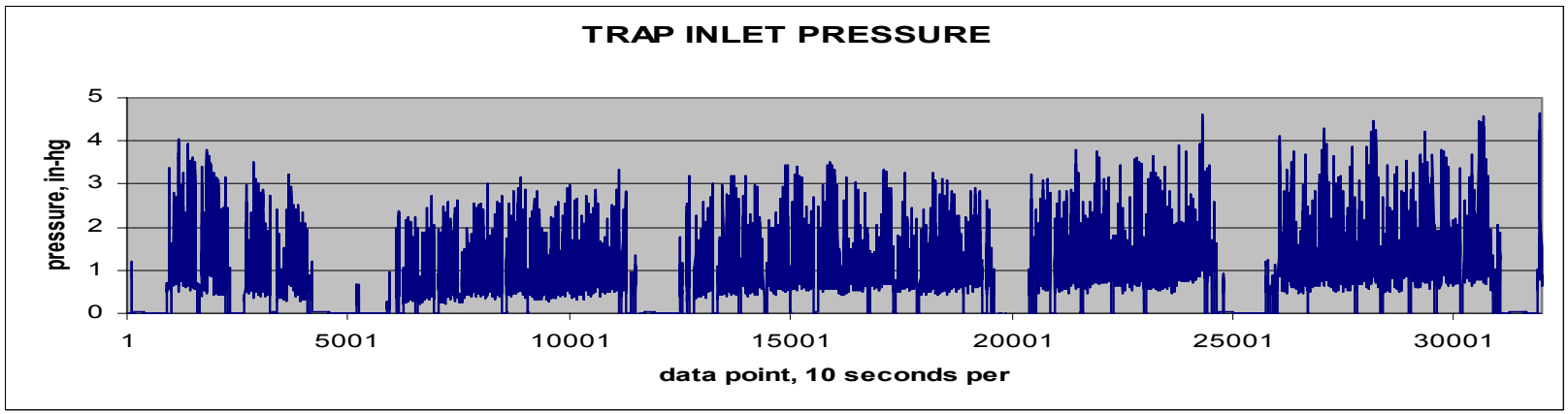
- Particulate trap field test on hybrid diesel-electric buses in NYC
- Test run January to July 2001
- Five buses
- Four high precious metal (high pm) traps
- Three low pm traps
- Other variations in catalyst formulation
- Variations in hybrid control strategy
- Variations in insulation and canning design
- Development of condition monitoring and warning strategy
- Traps were monitored for inlet temperature, outlet temperature,ambient temperature, and trap inlet pressure
- Related test cell work was also done

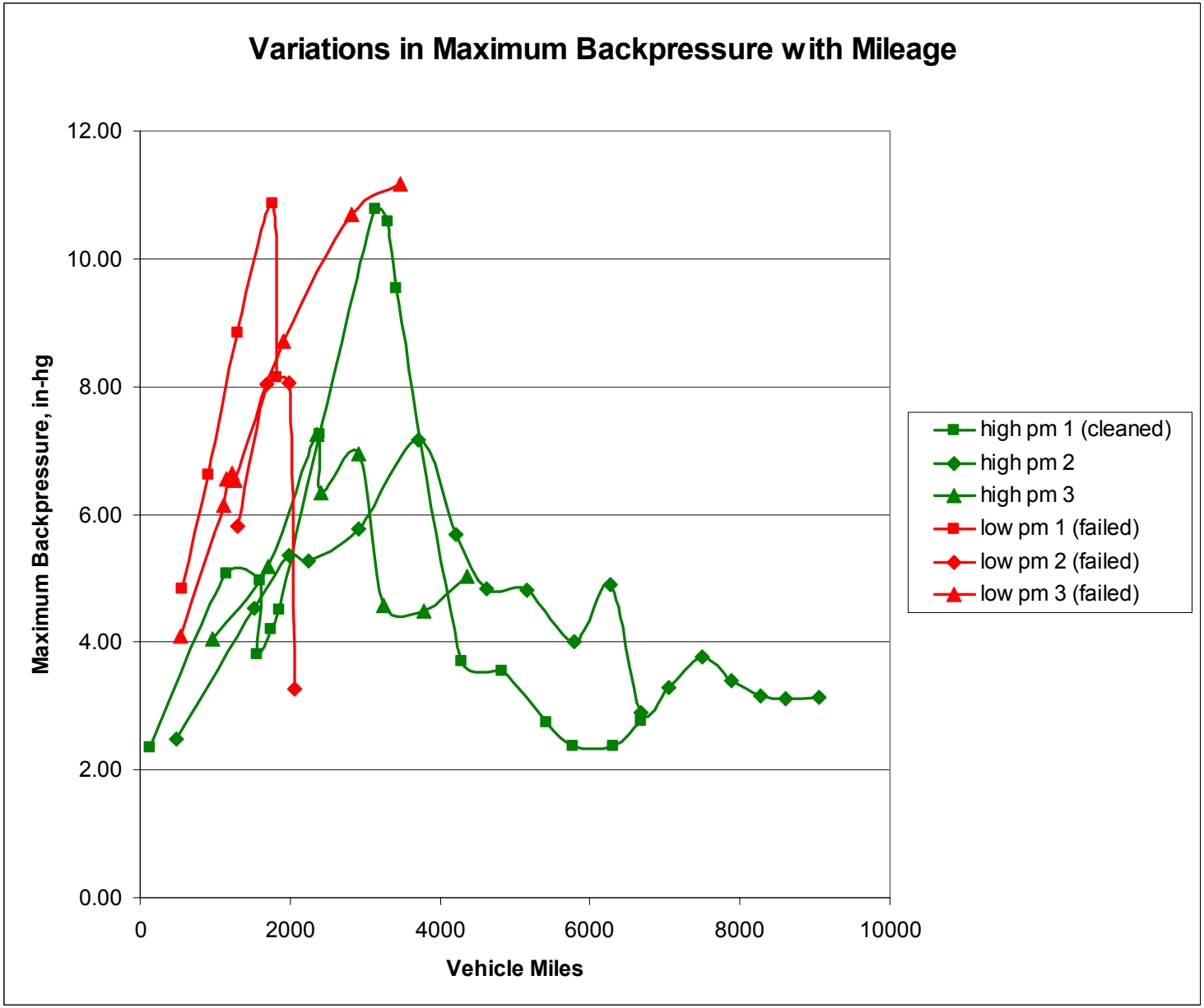
Definitions

- BALANCE POINT: the temperature above which soot is burned in the trap at the same rate it is accumulating and backpressure remains constant.
- 10% TEMPERATURE: the trap inlet temperature which is exceeded for 10% of the time while engine is running, used to characterize application duty cycle.
- UNCONTROLLED REGENERATION: when soot burning exceeds the rate that released heat is being removed from the trap, this can result in substrate overheating and failure.

Bus 6358, 3/16/01 to 3/22/01







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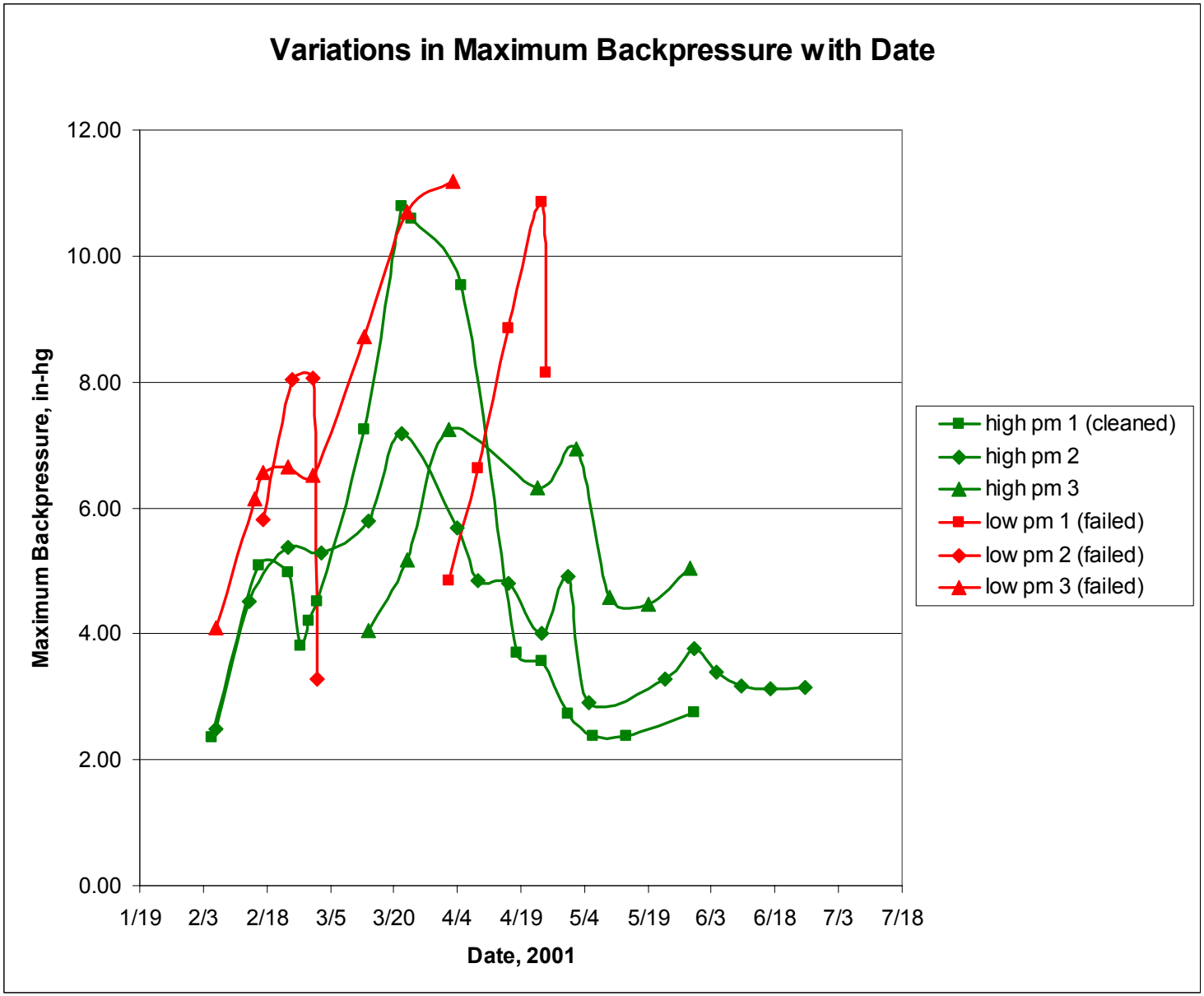

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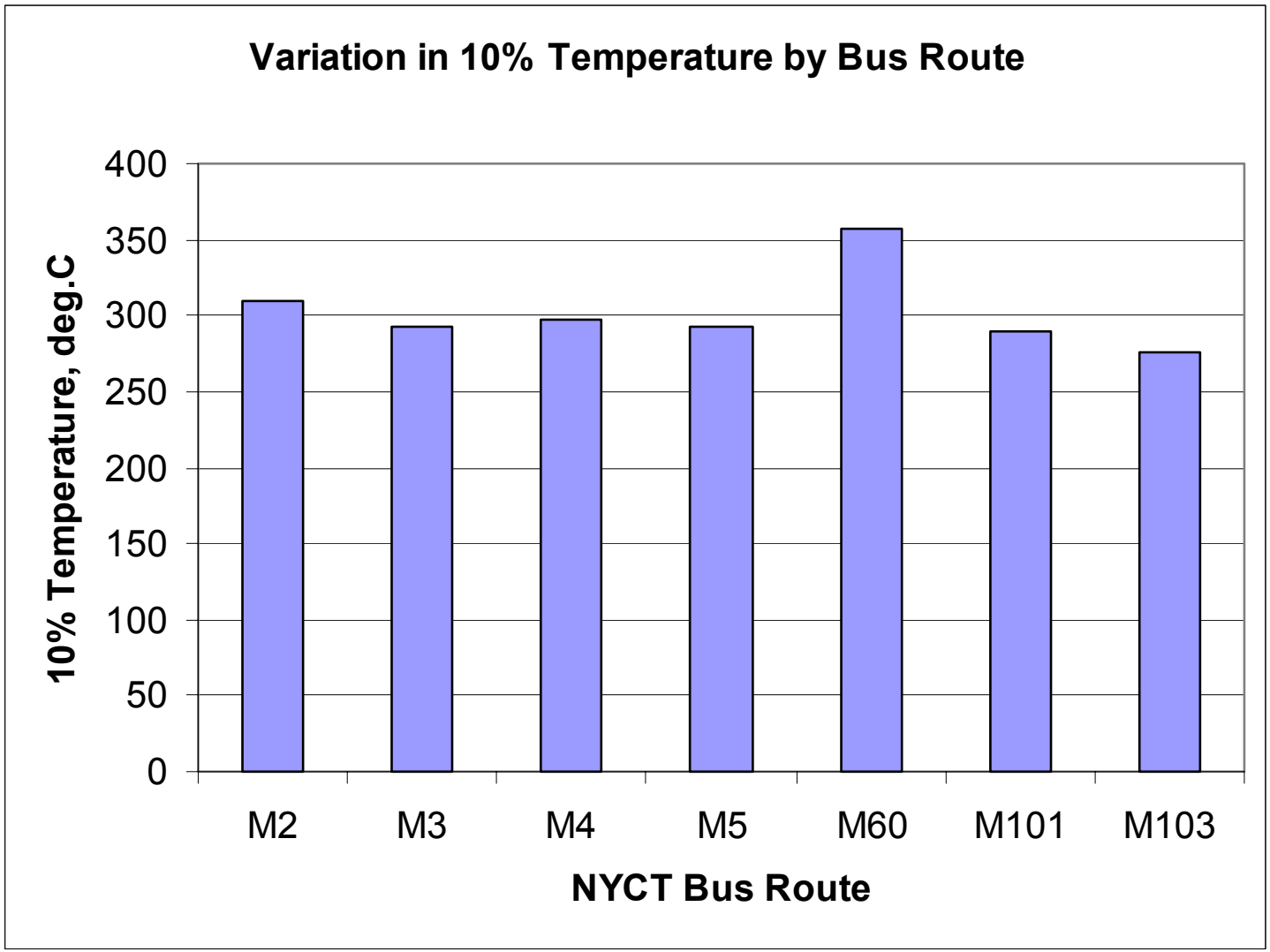

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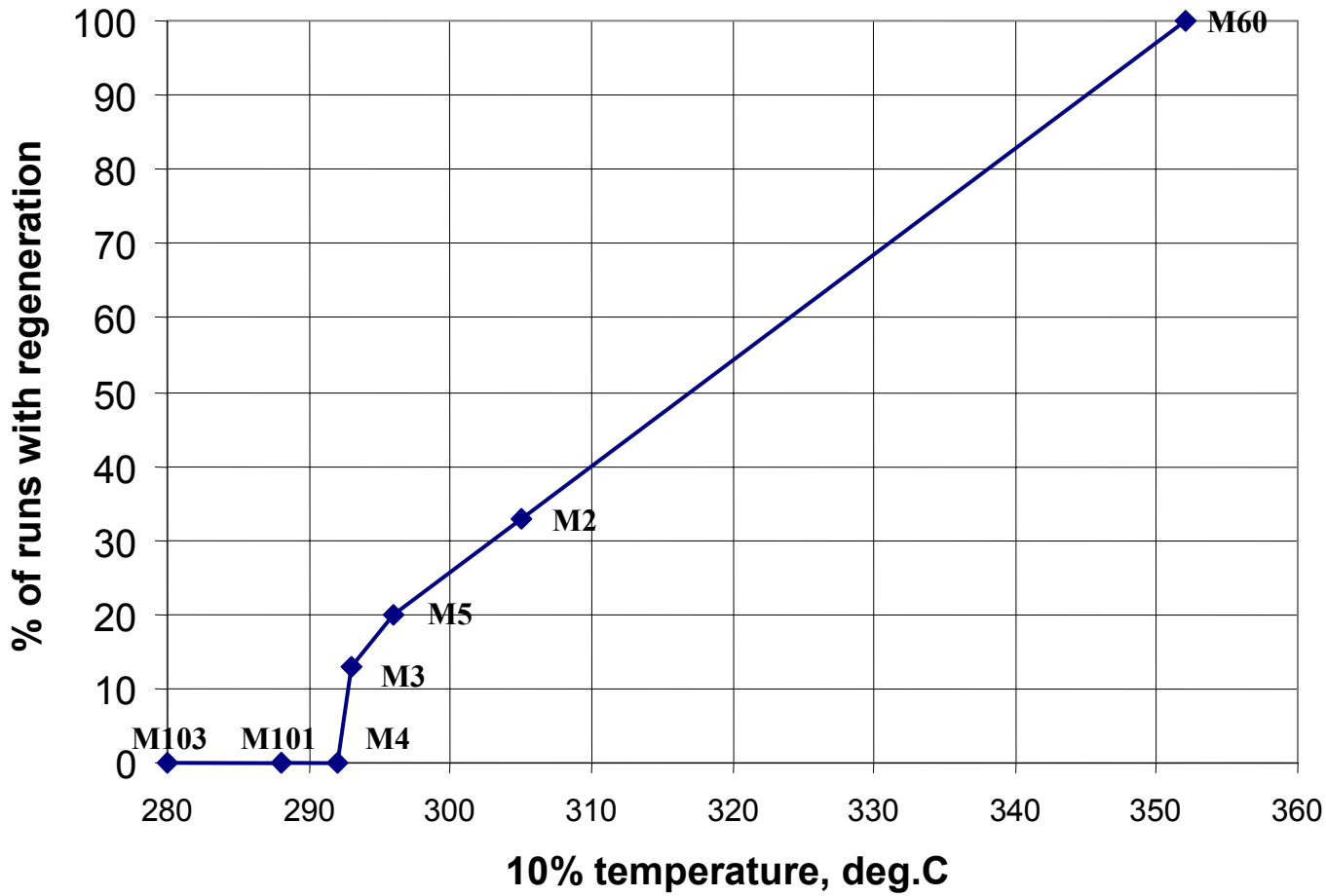
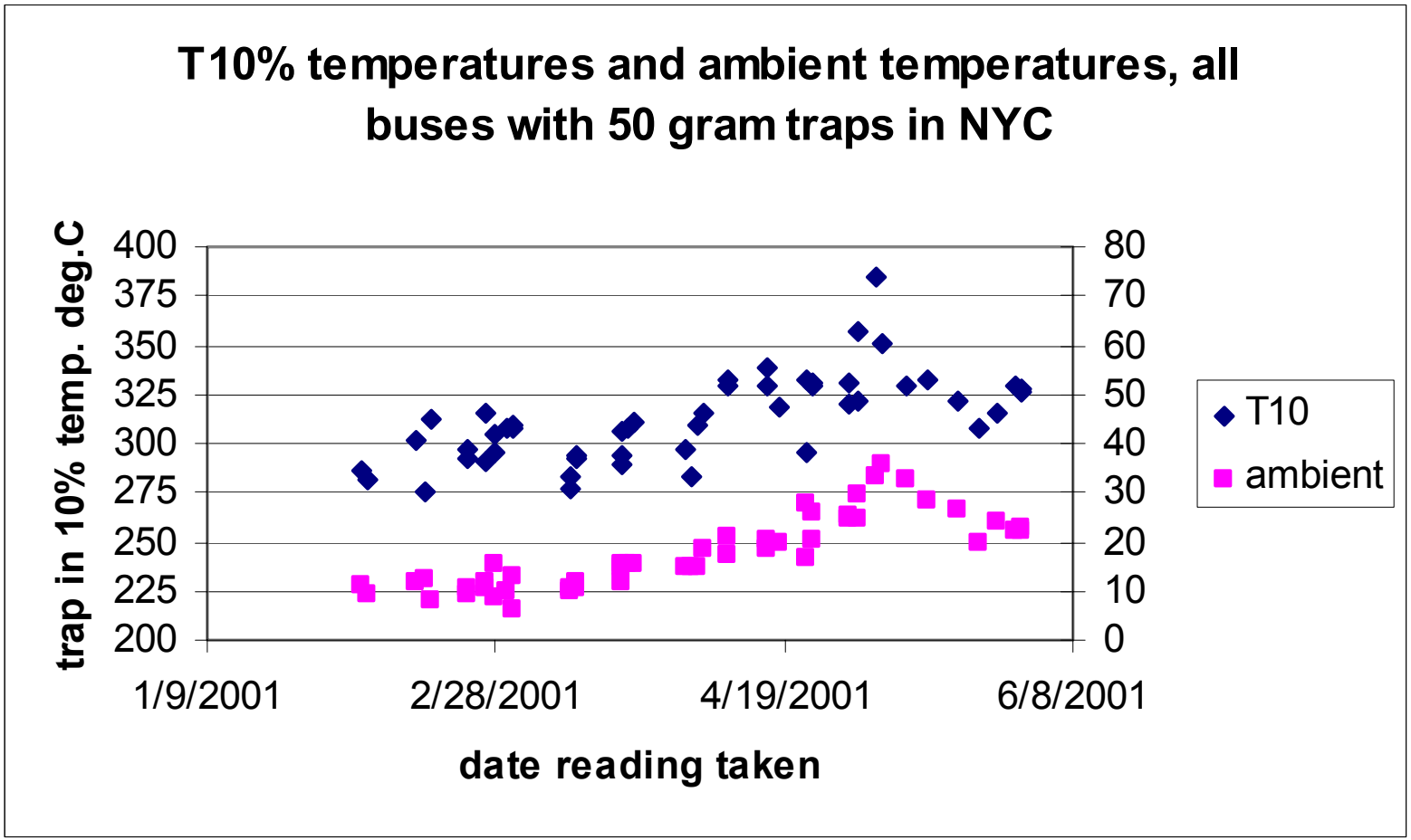
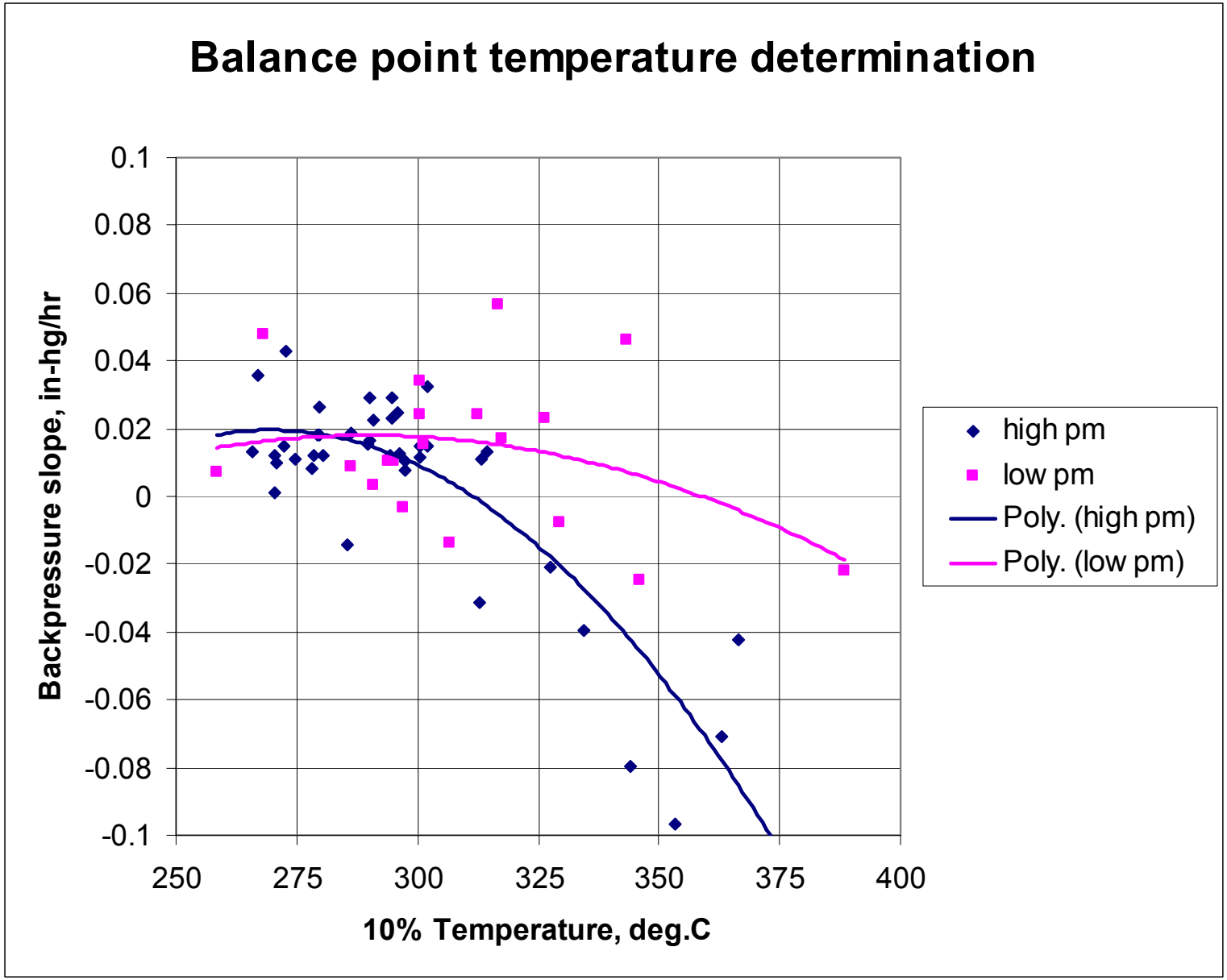
Figure 14, temperature / regeneration line, winter NYC




T10% temperatures and ambient temperatures, all buses with 50 gram traps in NYC
trap in 10% temp. deg.C
400
375
350
325
300
275
250
225
200
80
70
60
50
40
30
20
10
0
1/9/2001
2/28/2001
4/19/2001
6/8/2001
date reading taken
T10
ambient



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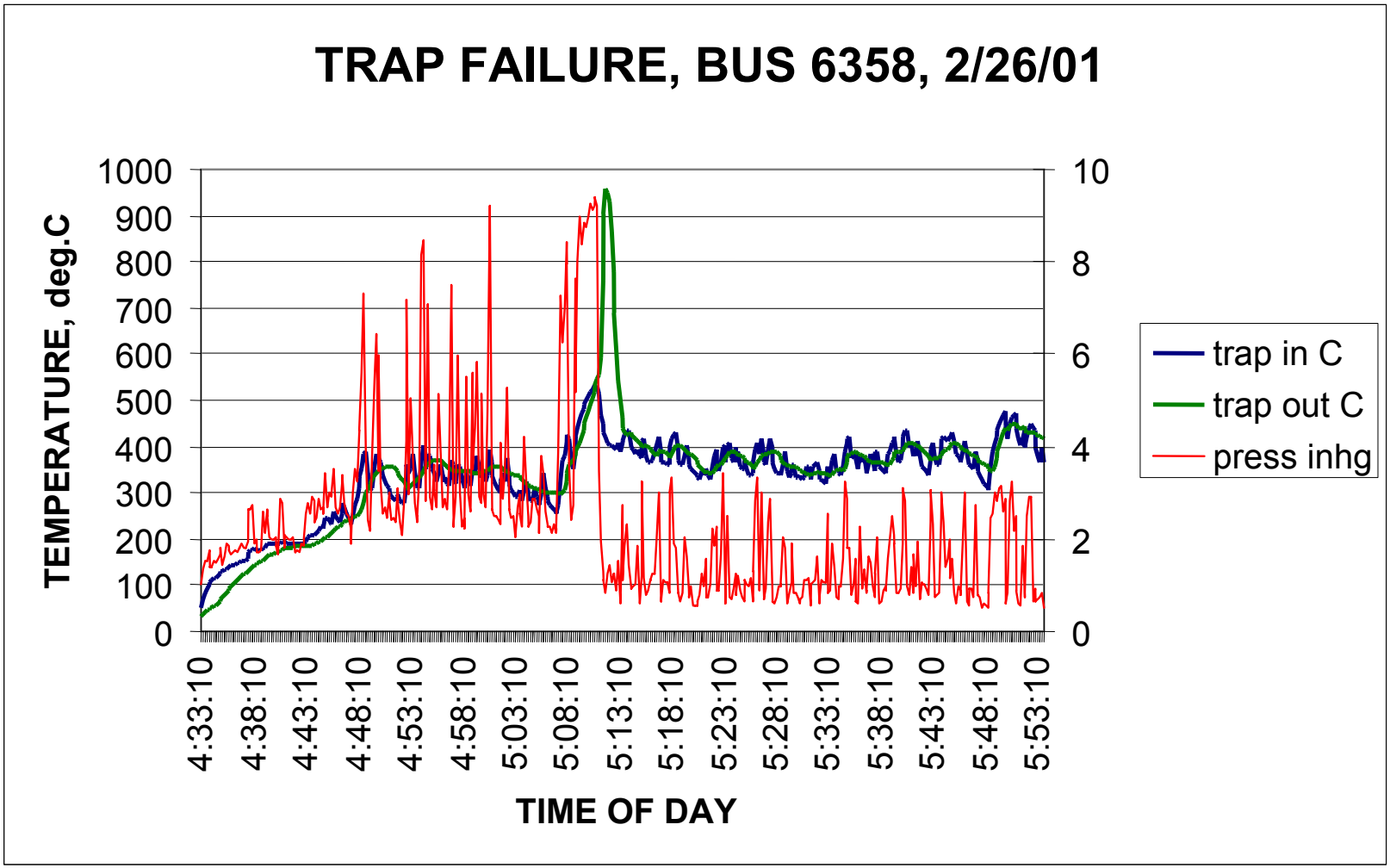
Uncontrolled regeneration

- Occurs when a particulate trap accumulates excess soot and does not continuously regenerate.
- Excess soot can be lit off during high load operation (hill, ex-way).
- If engine drops to idle during this burning, exhaust flow is too low to carry away the heat.
- Internal trap temperatures become high enough to melt portions of ceramic substrate.
- Damaged substrate no longer controls particulate emissions.
- Three out of 3 failures for low pm traps.
- No failures for 4 high pm traps.
- Uncontrolled regeneration can be prevented.


TRAP FAILURE, BUS 6358, 2/26/01
TEMPERATURE, deg.C
1000
900
800
700
600
500
400
300
200
100
0
10
8
6
4
2
0
4:33:10
4:38:10
4:43:10
4:48:10
4:53:10
4:58:10
5:03:10
5:08:10
5:13:10
5:18:10
5:23:10
5:28:10
5:33:10
5:38:10
5:43:10
5:48:10
5:53:10
TIME OF DAY
trap in C
trap out C
press inhg

Conclusions

- Hybrid buses are an extremely challenging application for particulate traps because of low exhaust temperatures corresponding to lower engine duty cycle resulting from improved fuel mileage compared to conventional buses.
- 4 high pm particulate traps survived a 4 month winter field test on hybrid buses in NYC, covering distances of 4400 to 9000 miles.
- The high pm traps accumulated excess backpressure and should have been cleaned (one was). However, with the coming of warmer weather, backpressures are dropping to a satisfactory level.
- Three low pm traps failed by uncontrolled regeneration at mileages of 1800 to 3500 miles.
- Key learnings from field test were incorporated into production design

Design improvements incorporated in production design

- Lower engine out particulate
  - improved engine design
- Increased exhaust temperature
  - insulation
  - hybrid duty cycle changes
- Particulate trap condition monitoring and warning system
  - protection against uncontrolled regeneration
- Improved trap catalyst formulation
  - more active catalyst
- Improved canning
  - better flow distribution
  - lower pressure drop

Acknowledgements

- Cummins would like to thank the following groups for assistance, support, and participation in this field test

  - New York City Transit
  - Orion Bus
  - BAE Systems
  - Engelhard Corporation
  - Nelson Industries
  - Cummins Metropower