The study of an Alumina-Based Lean NOx Trap (LNT) for Diesel

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Outline

- Introduction
- Sample preparation and Lab test condition
- Activities
- De-SOx
- Applications
- Discussion
- Conclusions

Introduction

- The exhaust temperature of light duty diesel vehicle is low (average cat inlet T<180°C) in urban driving cycles; current existing LNTs operate poorly below 200°C.
- Looking for materials to improve diesel LNT activities at low temperature (150 to 300°C).
- Alumina was studied as NOx storage materials in a new diesel LNT.
- The new diesel LNT has high NOx activities at low temperature. Its de-SOx process can be very efficiently performed at 600 to 650°C without noticeable thermal damage to the LNT.

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Catalyst preparation

- New (alumina) LNT preparation
  - Started from core samples with coated alumina washcoat (Al_2O_3: nominal loading)
  - Some alumina washcoats were modified by adding small amount of alkaline earth metal (2 to 3wt% of Mg, Ca, Sr or Ba) through soaking the samples in solution, such as Sr acetate, etc.
  - Precious metals were added to the new LNT through the Subtractive Deposition Method with similar loadings (typically Pt/Rh: 100/20g/ft^3) to a conventional (BaO on alumina) LNT
- New LNTs were later prepared by one of suppliers with different alumina loadings (nominal & two times of nominal loading)

Lab condition - evaluation and de-SOx

- Evaluation conditions
  - Sample size: 1 inch diameter & length
  - Lab test gas compositions (SV of 30,000 hr^{-1})
- Sulfur poisoning and de-SOx conditions
  - Load sulfur (SO_2) 1.15g/lit at lean condition (30ppm for 3000 seconds)
  - De-SOx at 600 to 650^oC slightly rich (λ = 0.98 to 0.987) for 1 to 2 minutes

Lab test gas compositions

Gas	Lean	Rich
CO	500ppm	4%
H_2	167ppm	1.33%
C_3H_6	300ppm C1	5000 ppmC1
NOx	500ppm	500ppm
O_2	10%	1%
CO_2	5%	5%
H_2O	5%	5%
	λ=1.96	λ=0.90

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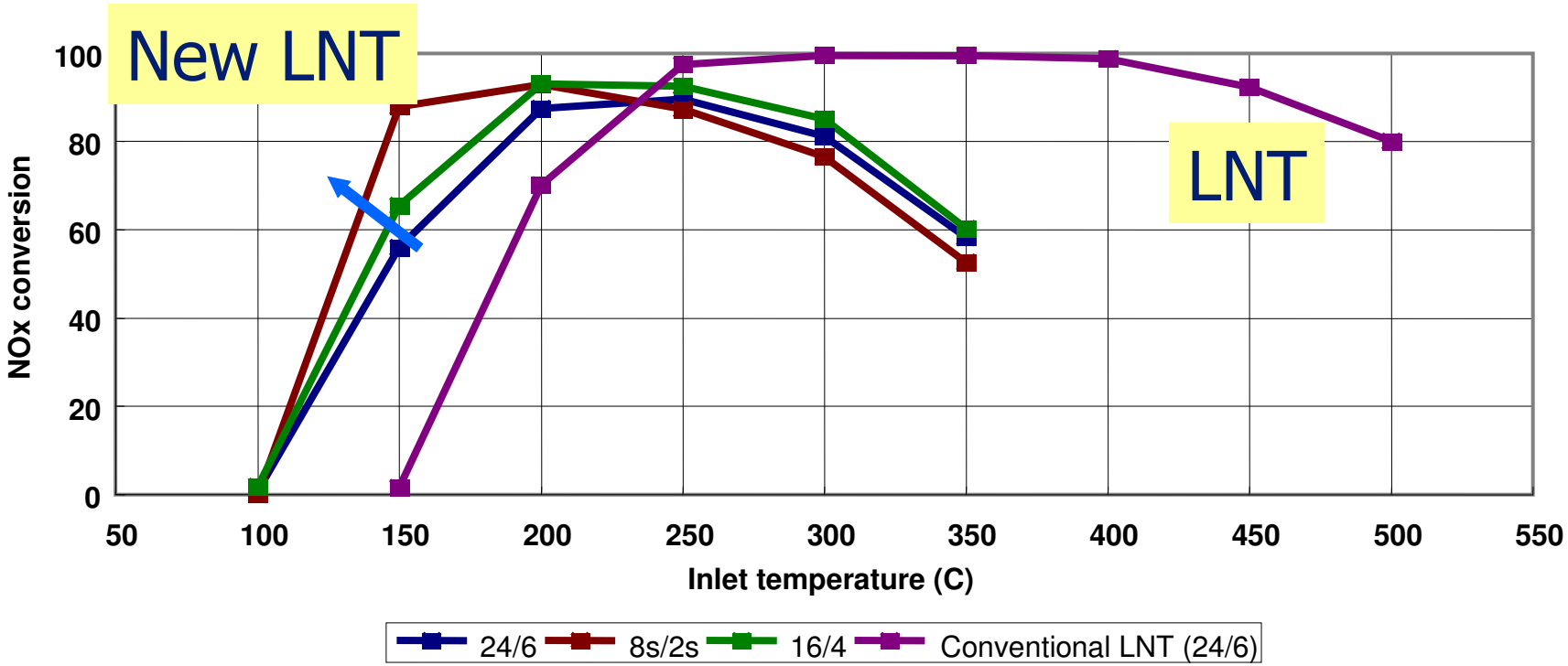
Conversion Comparison: New LNT to LNT

New LNT (after S poisoning & de-SOx) compared with a de-greened conventional LNT

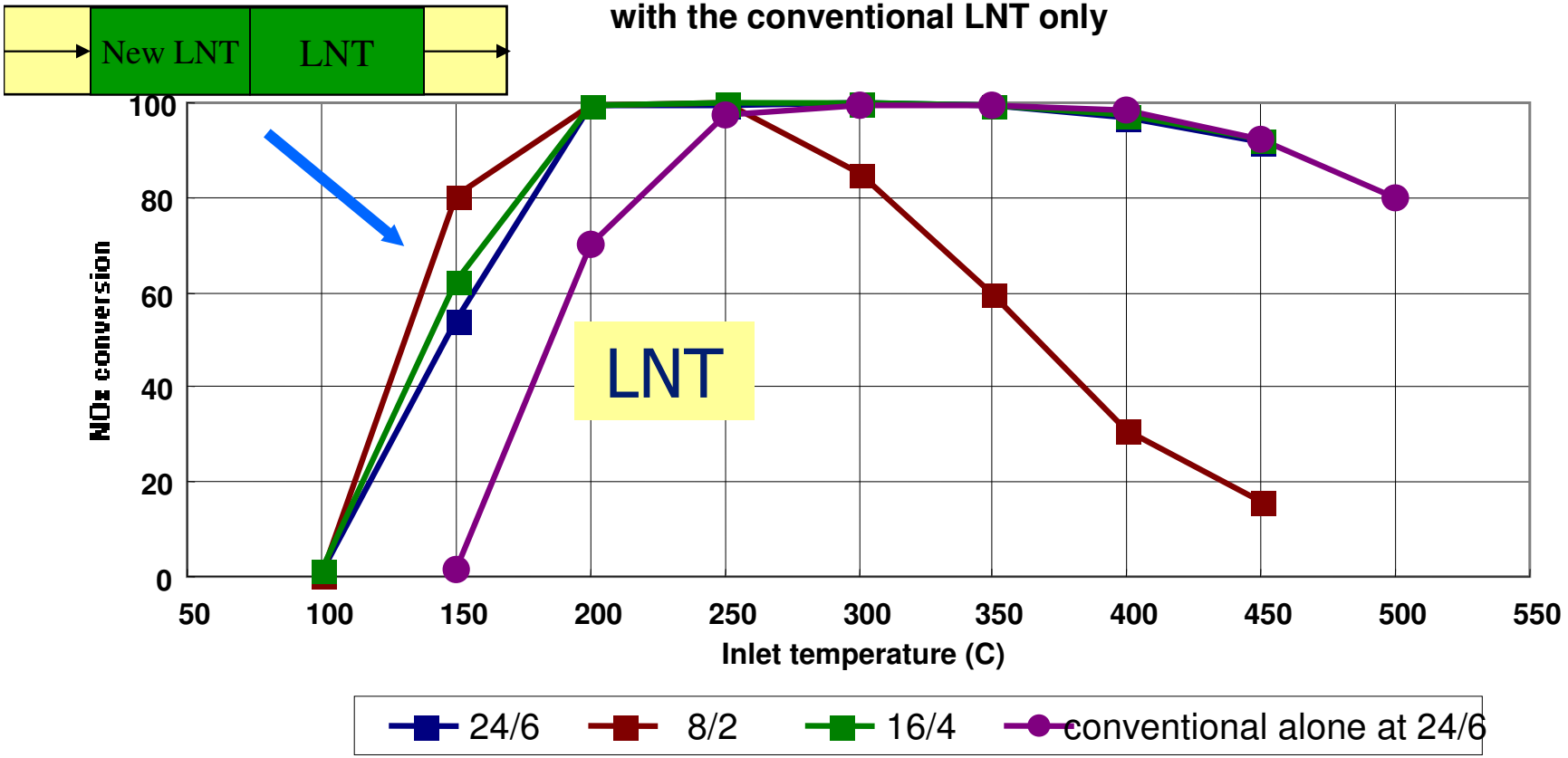


- Excellent low temperature conversion
- Better than any other catalyst to date
- Retained after sulfur loading and deSOx

*** 24/6: 24 second lean & 6 second rich

New LNT and LNT In Series

New LNT (after S poisoning & de-SOx) plus a conventional LNT compared with the conventional LNT only



*** 24/6: 24 second lean & 6 second rich

- Excellent system NOx conversion over a very wide temperature window

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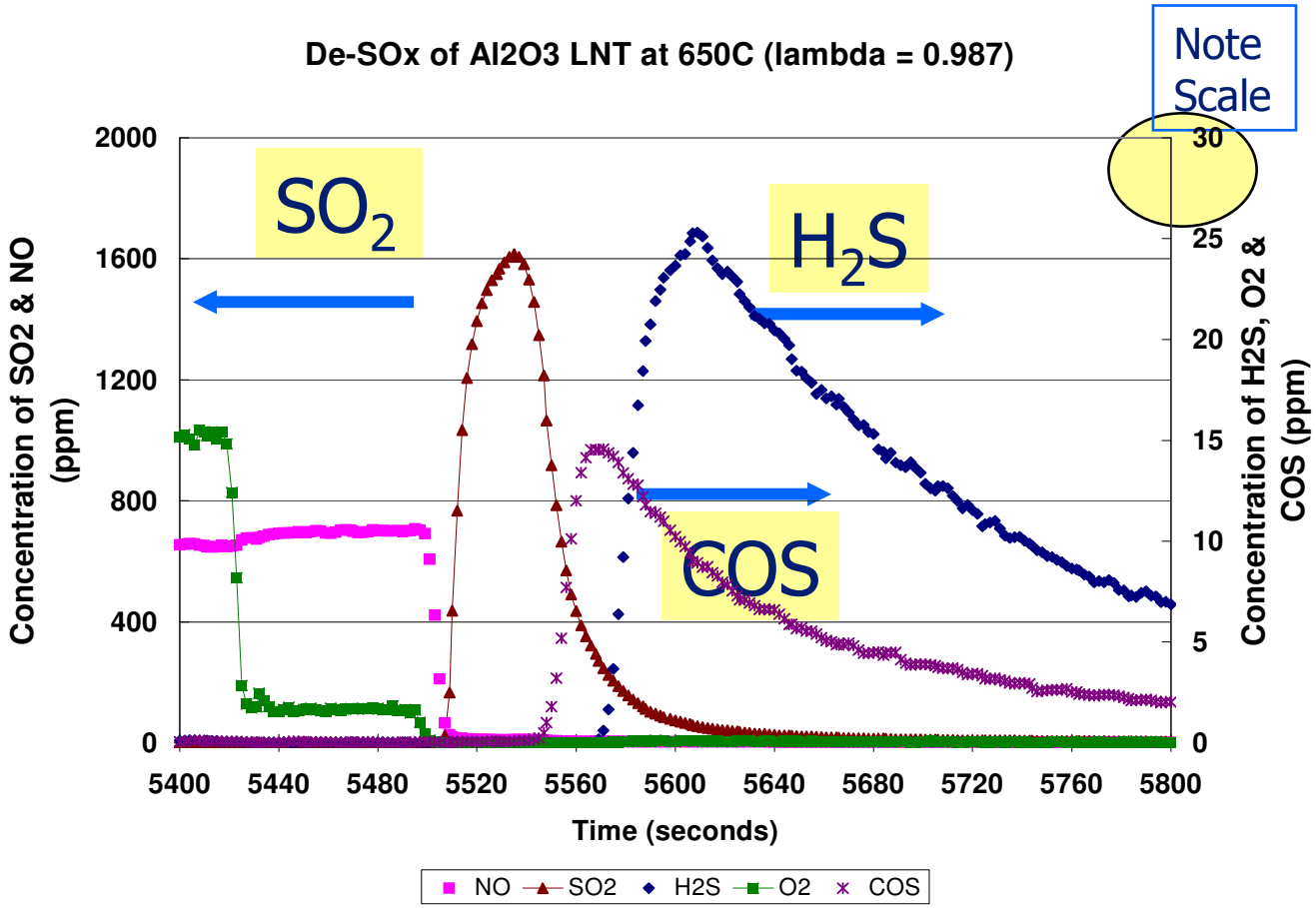
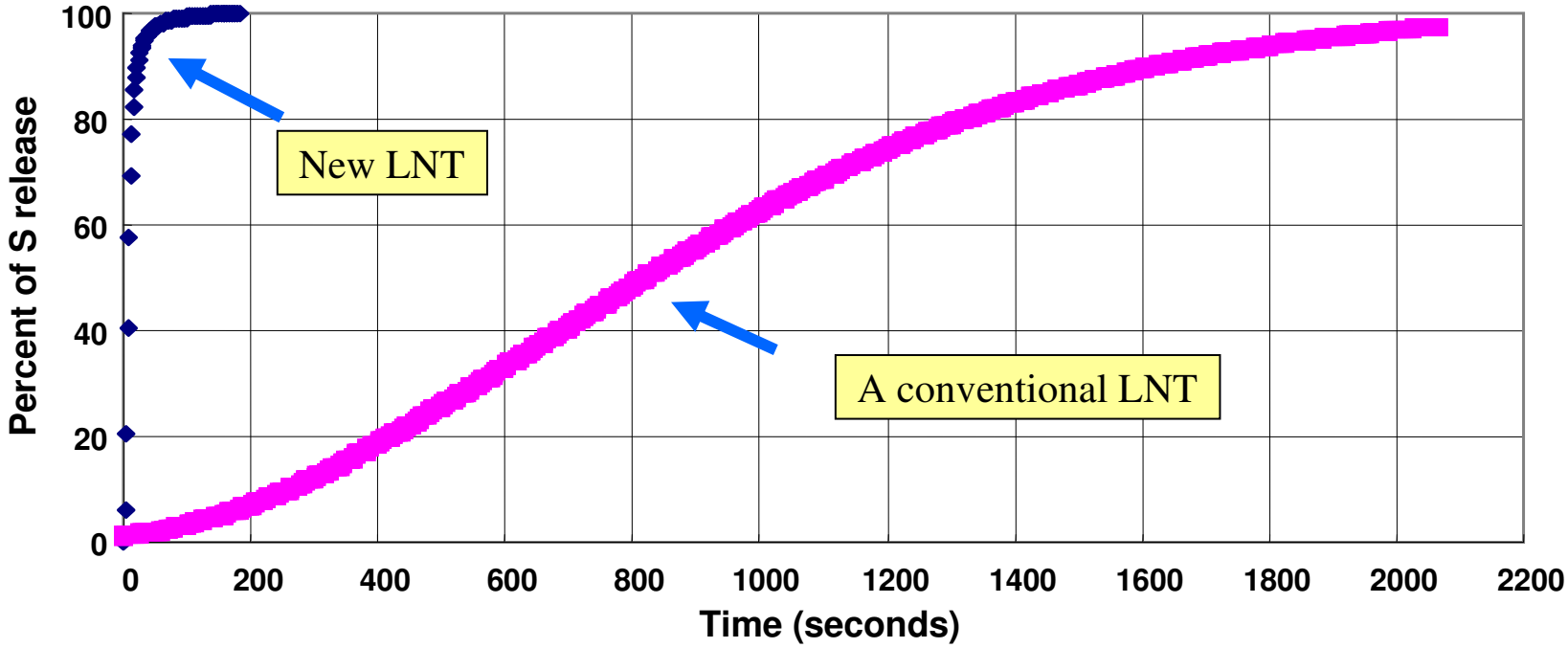
De-SOx of New LNT (sulfur loading 1.14g/liter)



- Lambda slightly rich, at 650°C
  - I.e., leaner than conventional LNT de-SOx
- Sulfur released quickly in about 1 minute, as SO_2
- Conventional LNT usually takes several minutes, gives H_2S

DeSOx of New LNT Versus LNT

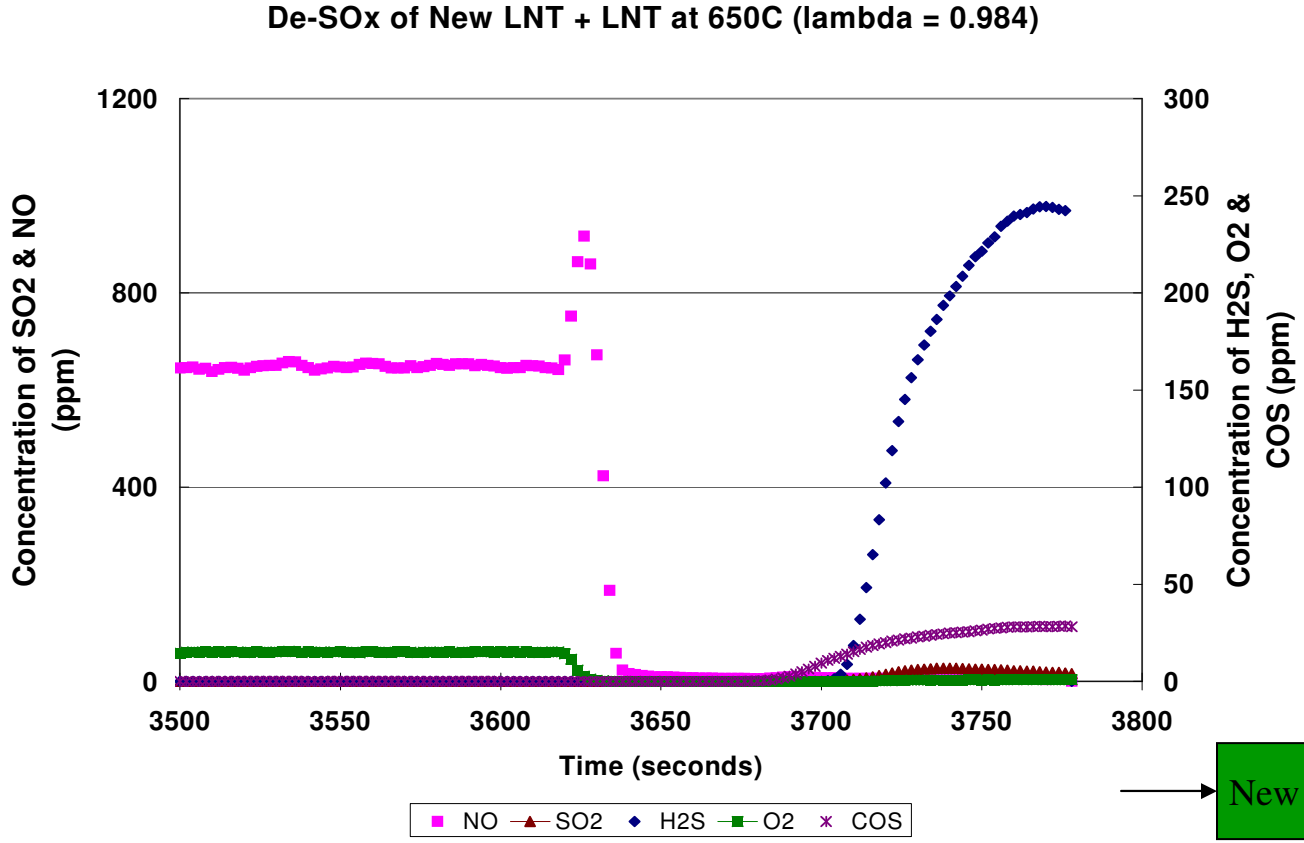
De-SOx of New LNT at 650C and λ of 0.98 compared with a typical conventional LNT (starting at 650C, heated to 800C at 5C/min) at 5/15 (lean/rich: lambda 2.0/0.9)

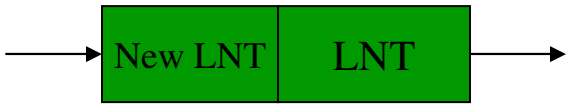


- Much faster rate of sulfur release
- Therefore, needs less time at high temperature
- Much less thermal damage
- Lower FE penalty

De-SOxing New LNT in Series with LNT

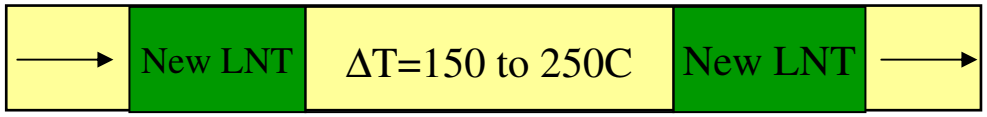
sulfur loading 1.14g/liter at the New LNT

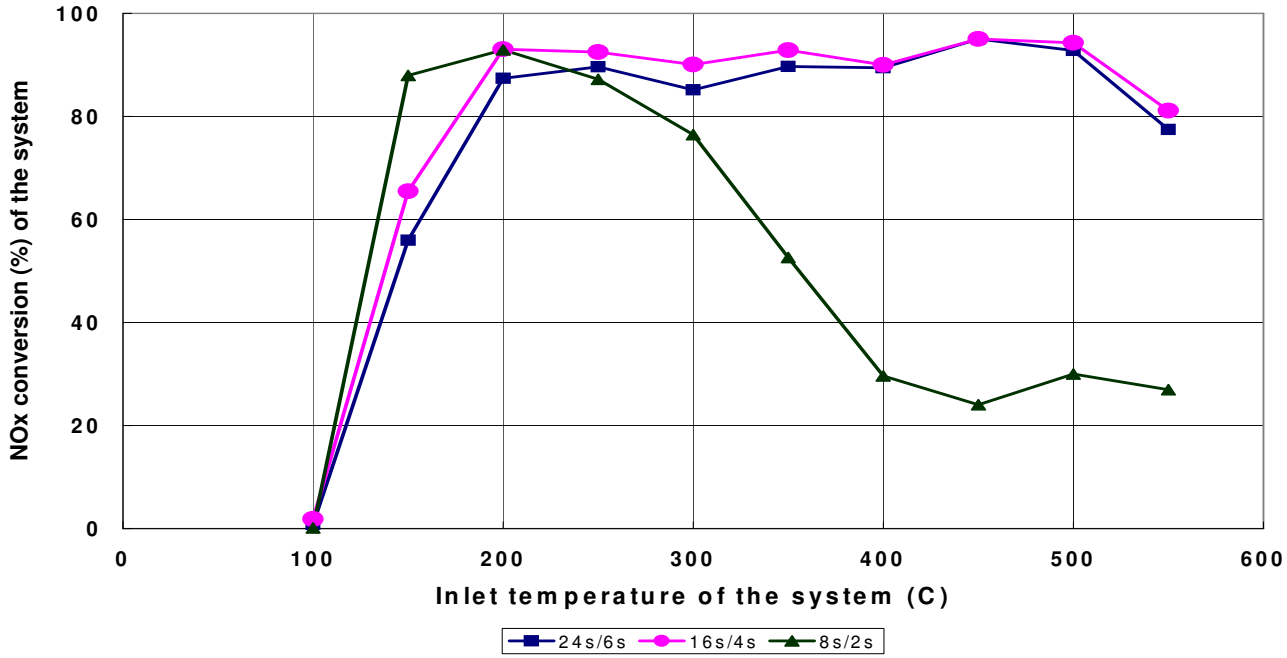




- SO_2 released from alumina LNT does *not* pass through LNT
- So, New LNT+LNT system would need conventional de-SOx

Two New LNT in Series

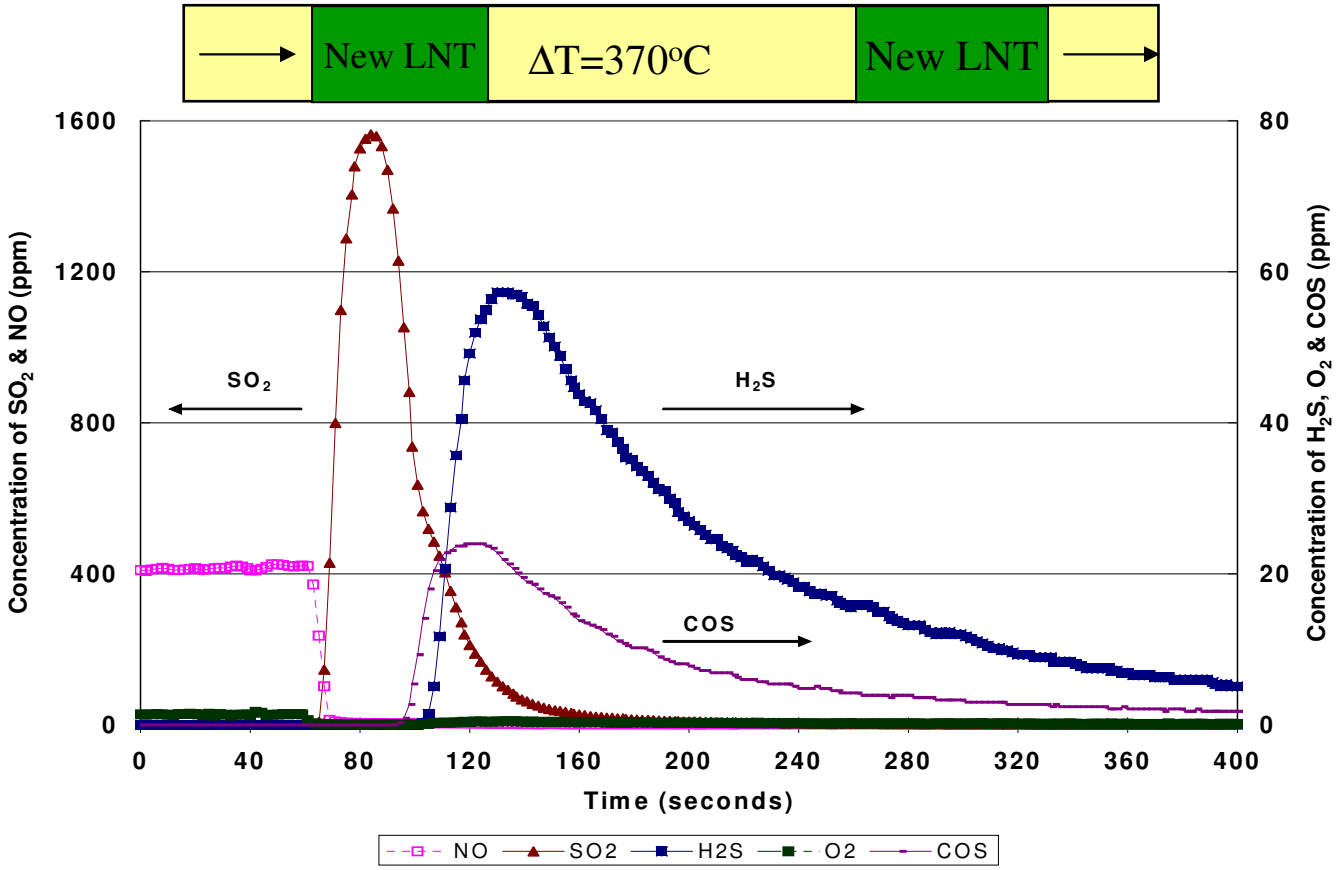




- Two catalysts in series (half the space velocity)
- Separated so second bed is cooler
- Gives very wide temperature range

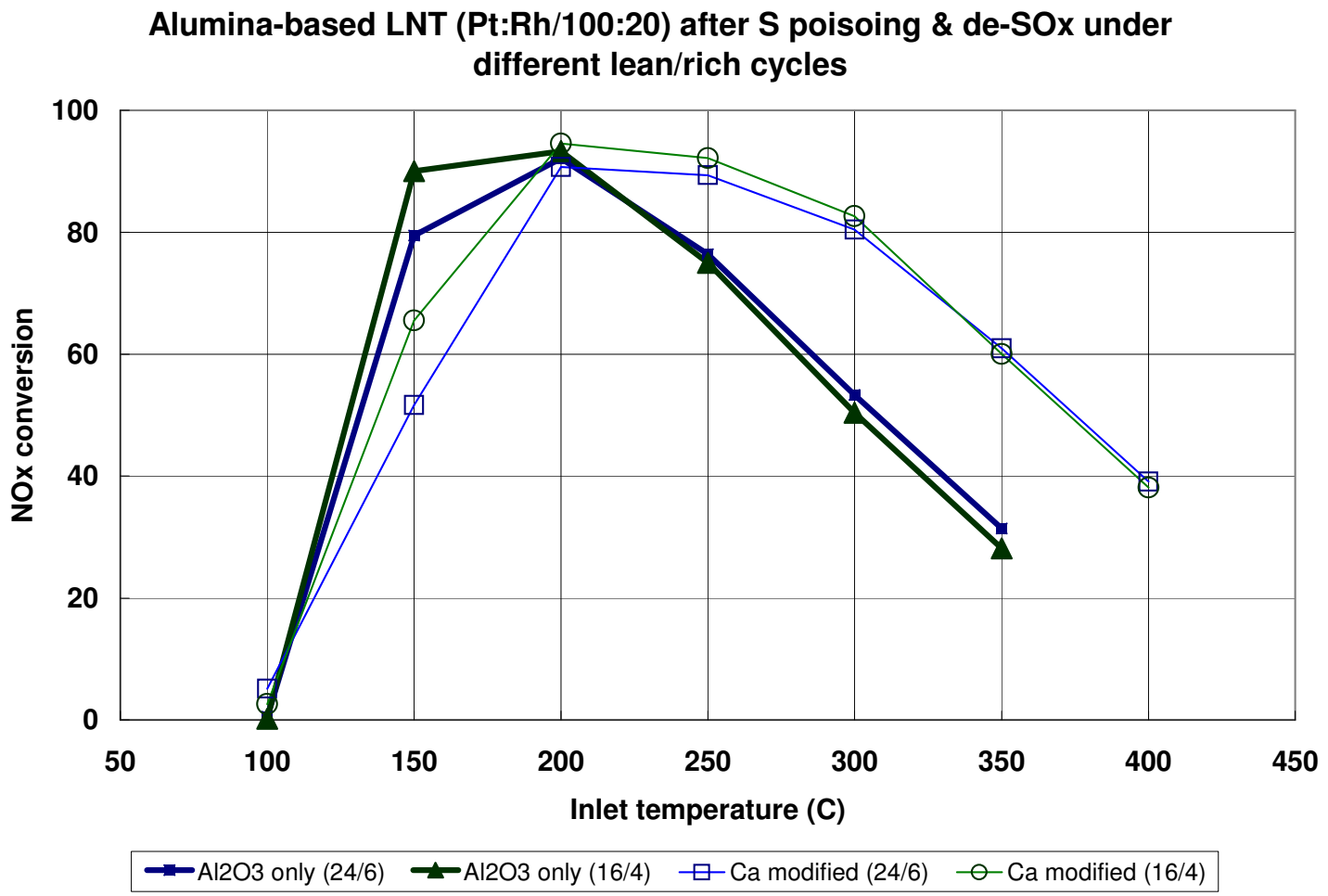
De-SOx of two New LNT in Series

First New LNT at 650°C and the second one at 280°C

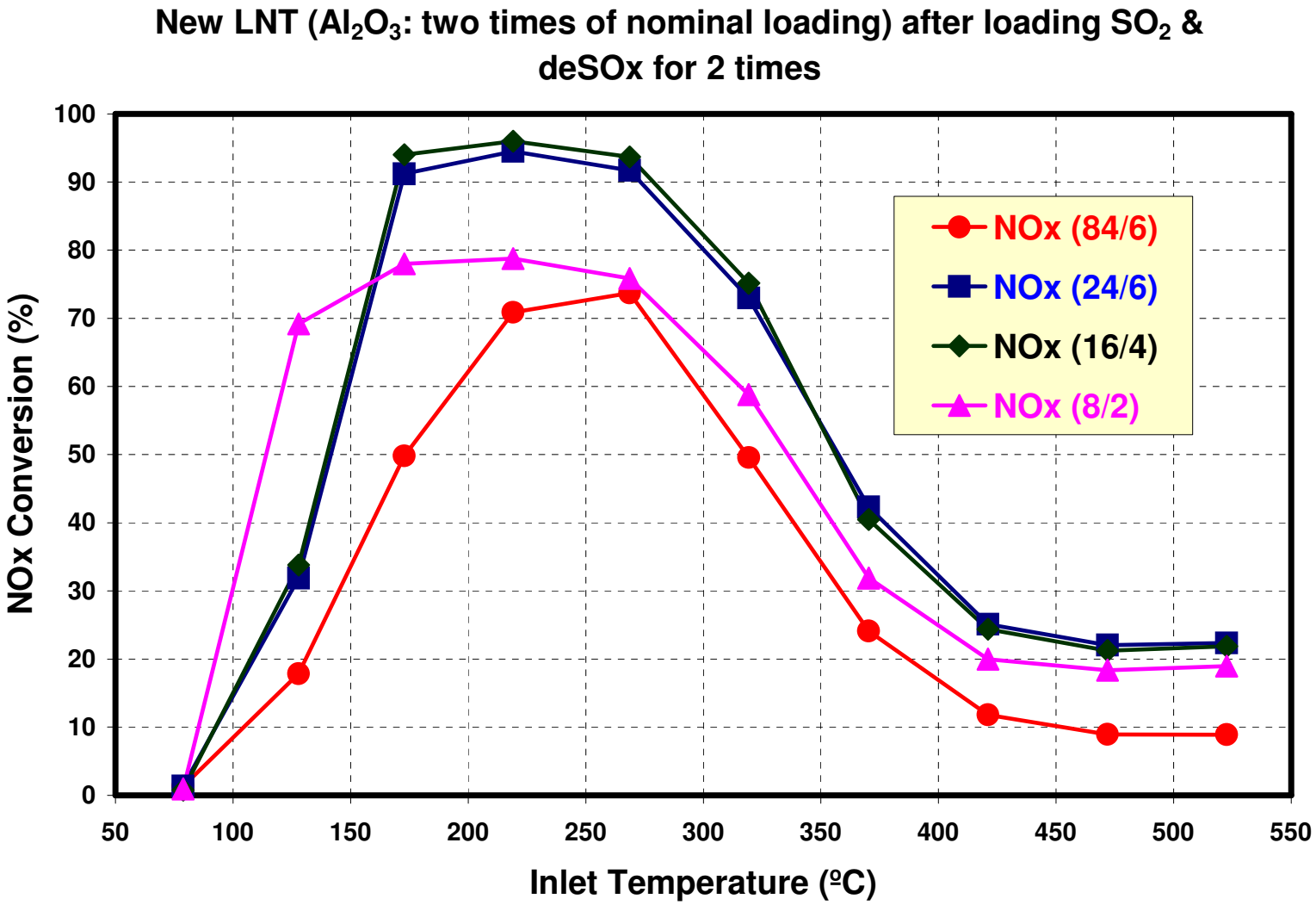


- S loading at the first New LNT 1.14g/liter & w/o S at the second one
- SO_2 released from first bed passes through second bed
- System has easy, fast de-SOx

Modification of Alumina based LNT by alkaline earth metals (2 to 3 wt%)



New LNT produced by a supplier



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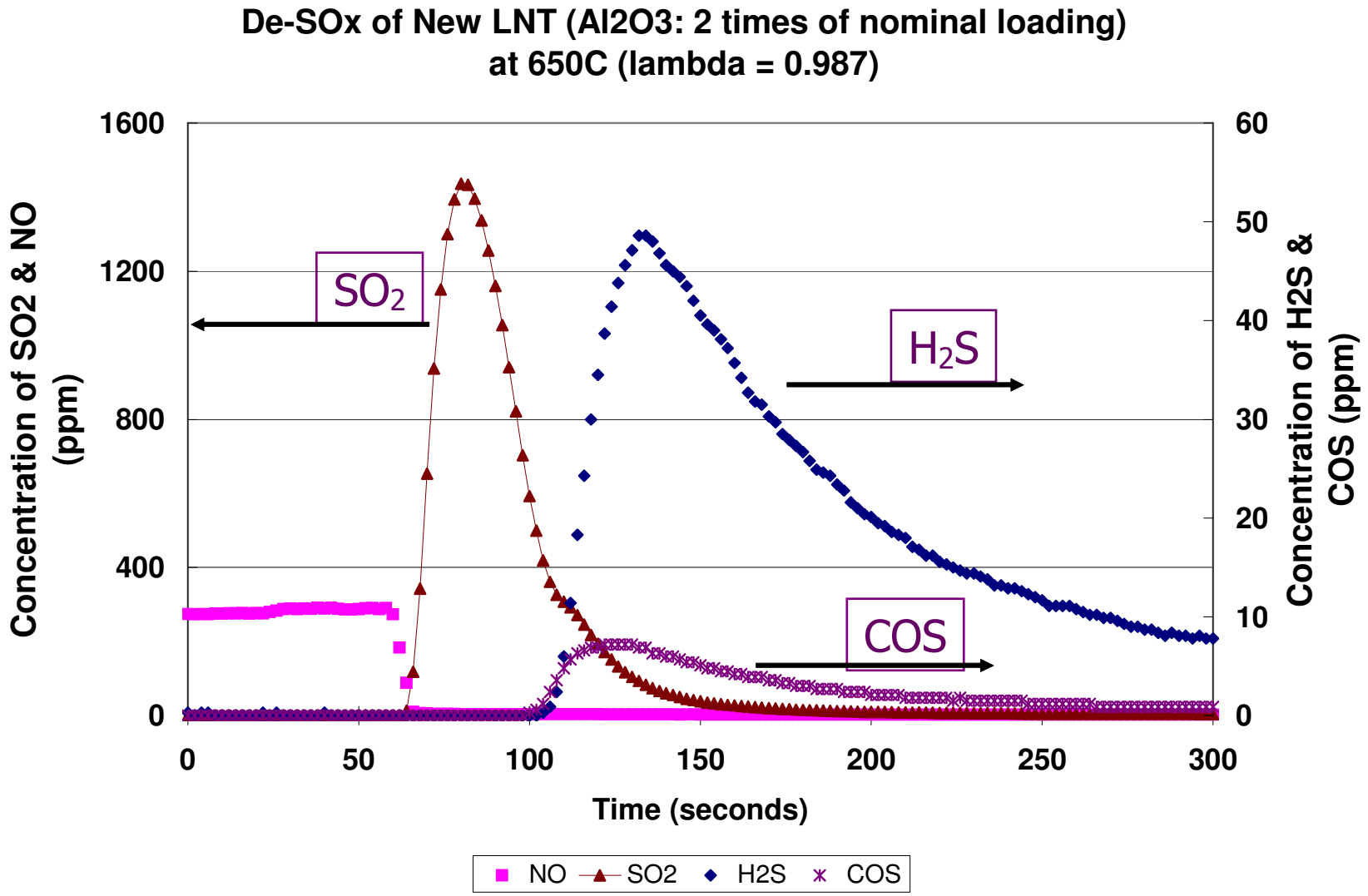
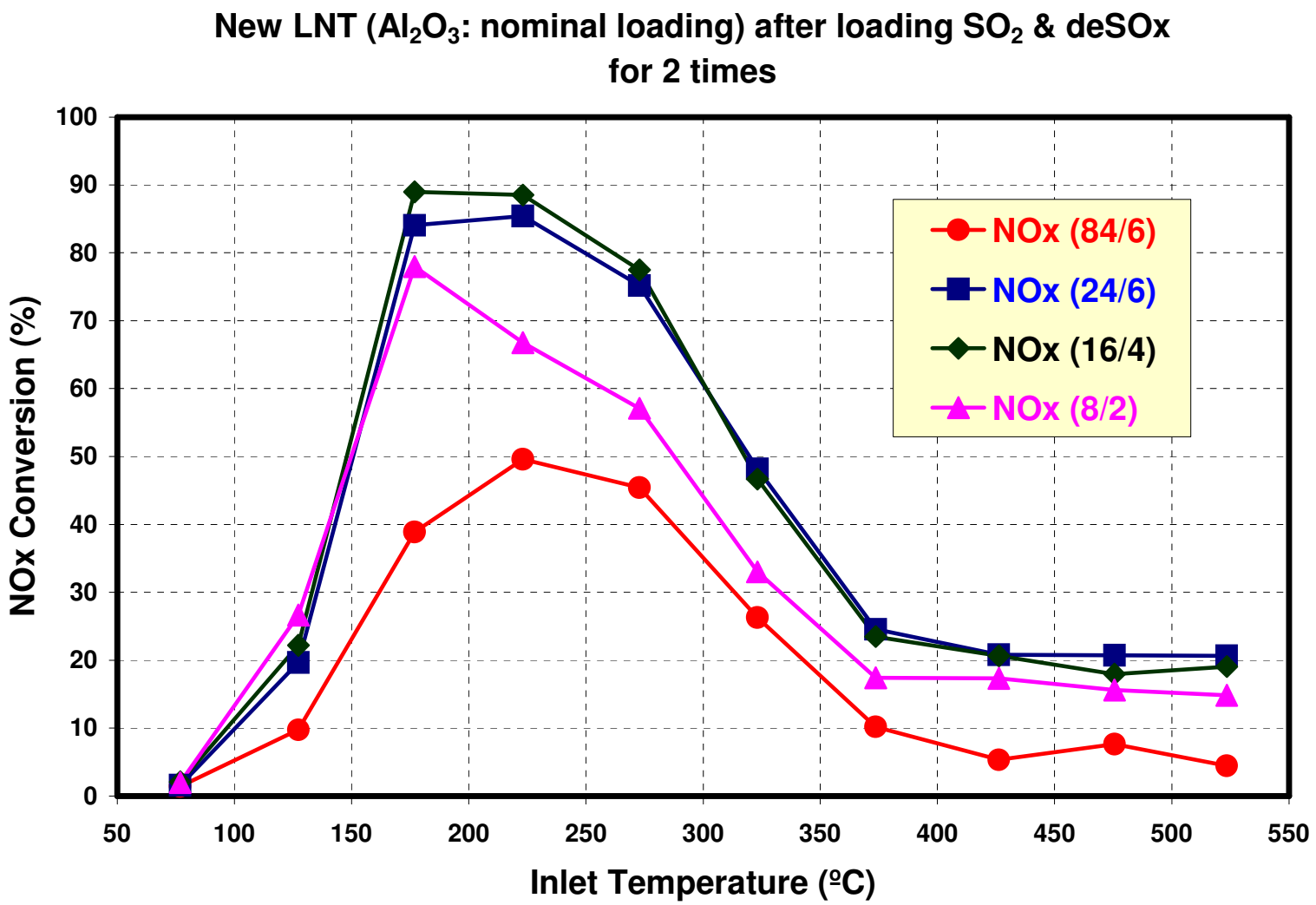
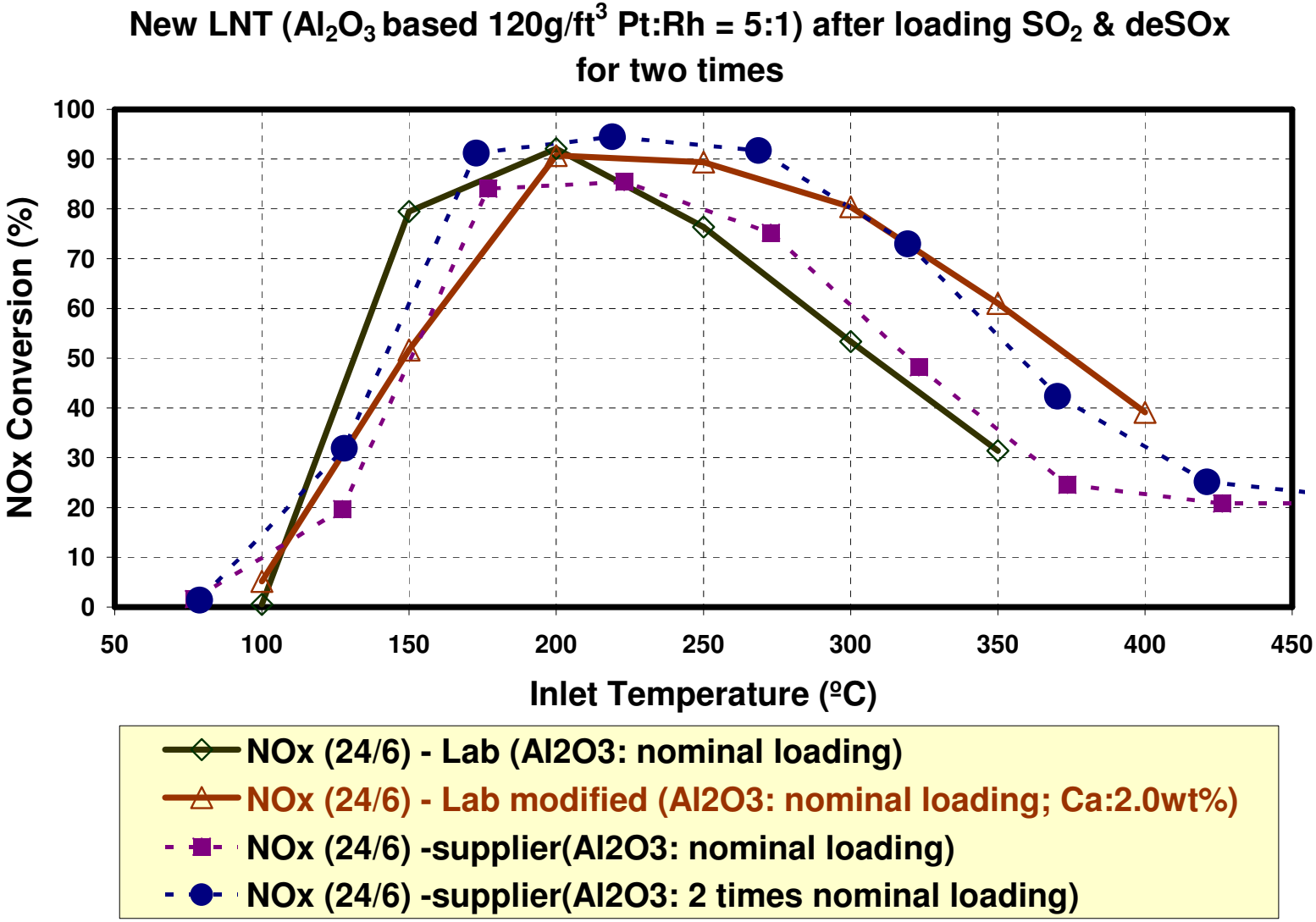


New LNT produced by a supplier



Alumina based LNTs compared



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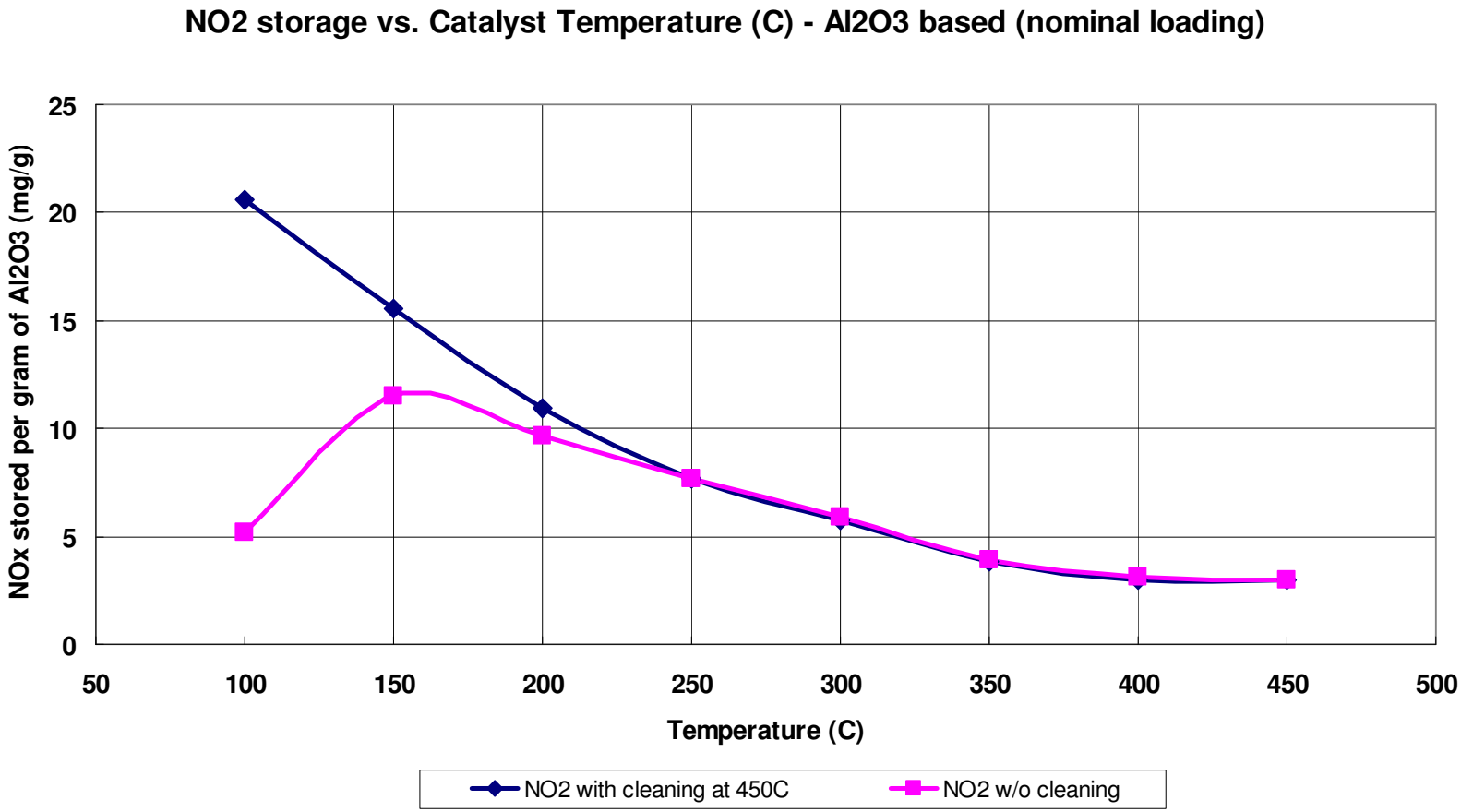
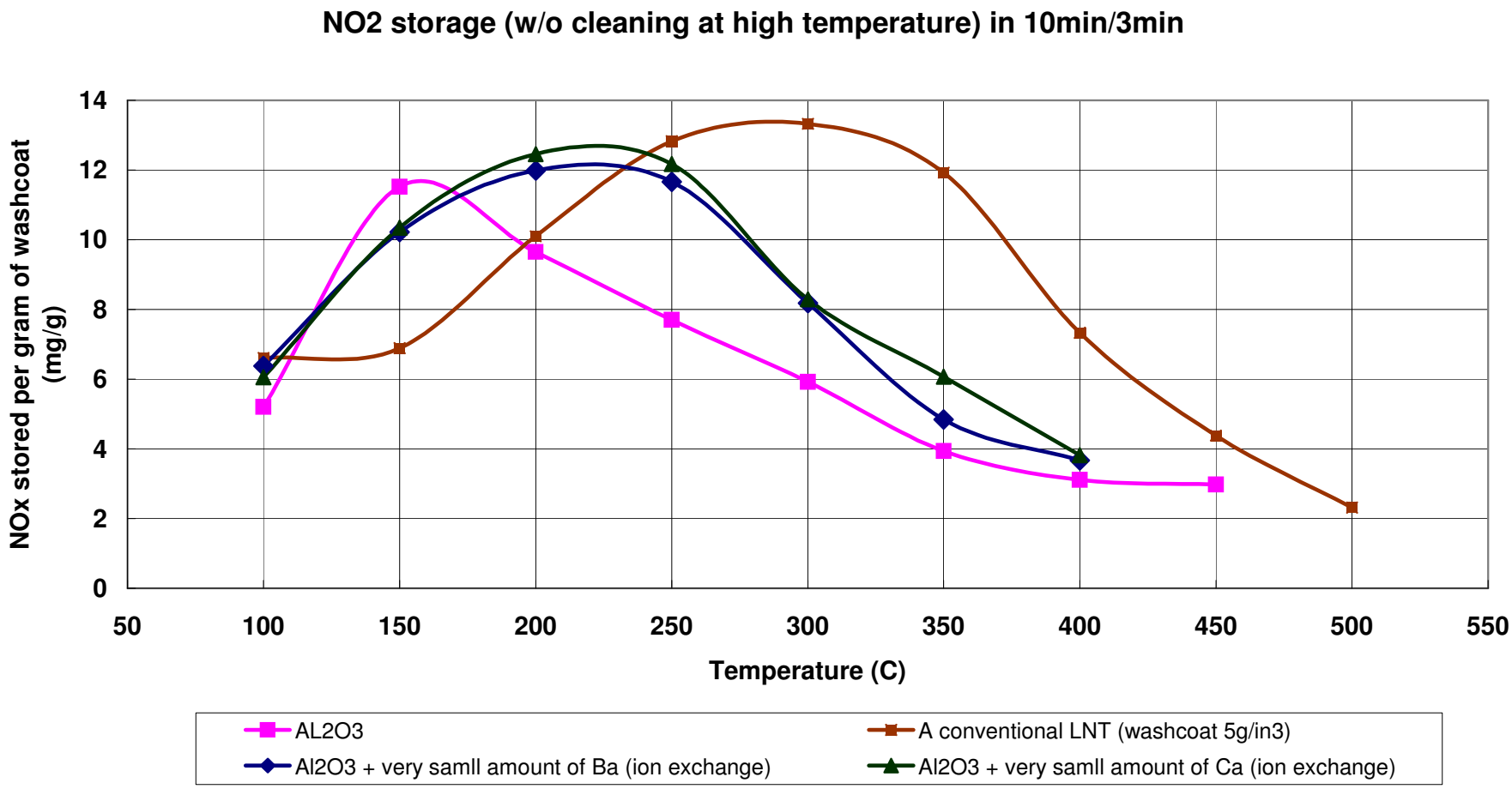


With cleaning: 1. heat sample to 450 to 550°C in N_2 for 10 min then cool down to the test temperature;
2. load NOx in lean condition until saturation;

Without cleaning: only run 10 min/3min lean/rich cycle at test temperature until stabilized;

Discussion (continued)



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Conclusions

- Alumina based (New) LNT provides high NOx conversion efficiencies at low temperature (150 to 300^{o}C)
- Unique de-SOx process of the New LNT
  - Very efficiently removes the S at slightly rich conditions
  - Short thermal exposure & Low fuel penalty
  - It could provide a solution to the current LNT durability issue caused by de-SOx process
- A Multiple New LNT system
  - Covers a wide temperature window with high NOx conversion efficiencies
  - Maintains unique de-SOx process of the New LNT
  - Such a system would work well with the catalyzed DPF and TWC (as in HCCI exhaust system)

Conclusions (cont.)

- Increased alumina loading provides high NOx shortage capacity and increases the NOx reduction efficiencies, especially in case of the lean/rich cycle with a long lean time (e.g. 84/6).
- Alkaline earth metal(2 to 3 wt%) modified alumina based LNTs also show high NOx activities at low temperatures with expanded temperature window and effective de-SOx with the same unique de-SOx process as the alumina only LNT.