Engine Tests of an Active PM Filter Regeneration System

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Abstract

Regulations for the 2007 model year diesel engines will almost universally require Particulate Matter (PM) filters to achieve the required particulate emissions level. For vehicle applications in which the exhaust temperature is low, significant challenges occur in obtaining light-off temperatures of the Diesel Oxidation Catalyst (DOC). Without this minimum temperature, filter regeneration cannot be activated through post-injected fuel and systems face risk of becoming overloaded with soot and eventually plugged.

An active PM filter regeneration technology has been developed in which diesel fuel is oxidized in the presence of a proprietary catalyst system, regenerating the PM filter in an efficient and controlled manner.

Abstract

Several important benefits for such a system include light off at low exhaust temperatures, which allows active regeneration over a wide range of vehicle uses, the ability to heat the PM filter uniformly without hot spots or uncontrolled temperature extremes, lower backpressures and fuel penalty costs and a control strategy disconnected from the engine management system.

The Xonon Fuel Combustor (XFC™) provides for active regeneration of the PM filter at various vehicle loads and speeds. System attributes include operation at engine exhaust temperatures as low as 220°C and an outlet temperature that can be efficiently controlled over a wide range, as high as 700°C.

Abstract

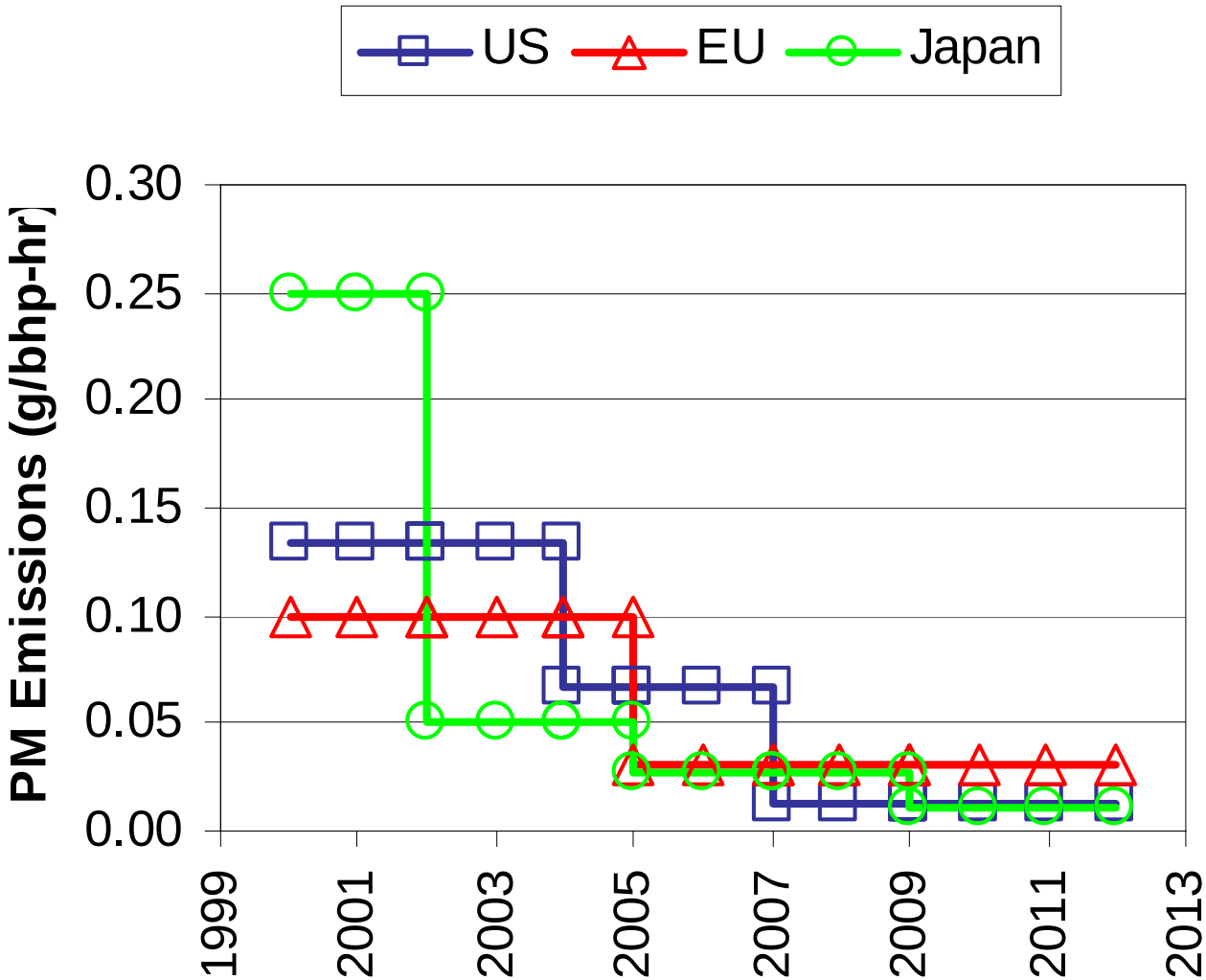
The system is designed to produce a highly uniform outlet gas stream for controlled regeneration of the PM filter. The integration of the XFC with a PM filter potentially allows for use of uncatalyzed filter substrates and lower cost substrate materials since the filter unit regeneration cycle can be carefully controlled and managed. Engine tests over a wide exhaust flow rate range showing system thermal response, PM filter regeneration and low temperature operation data is presented.

Outline

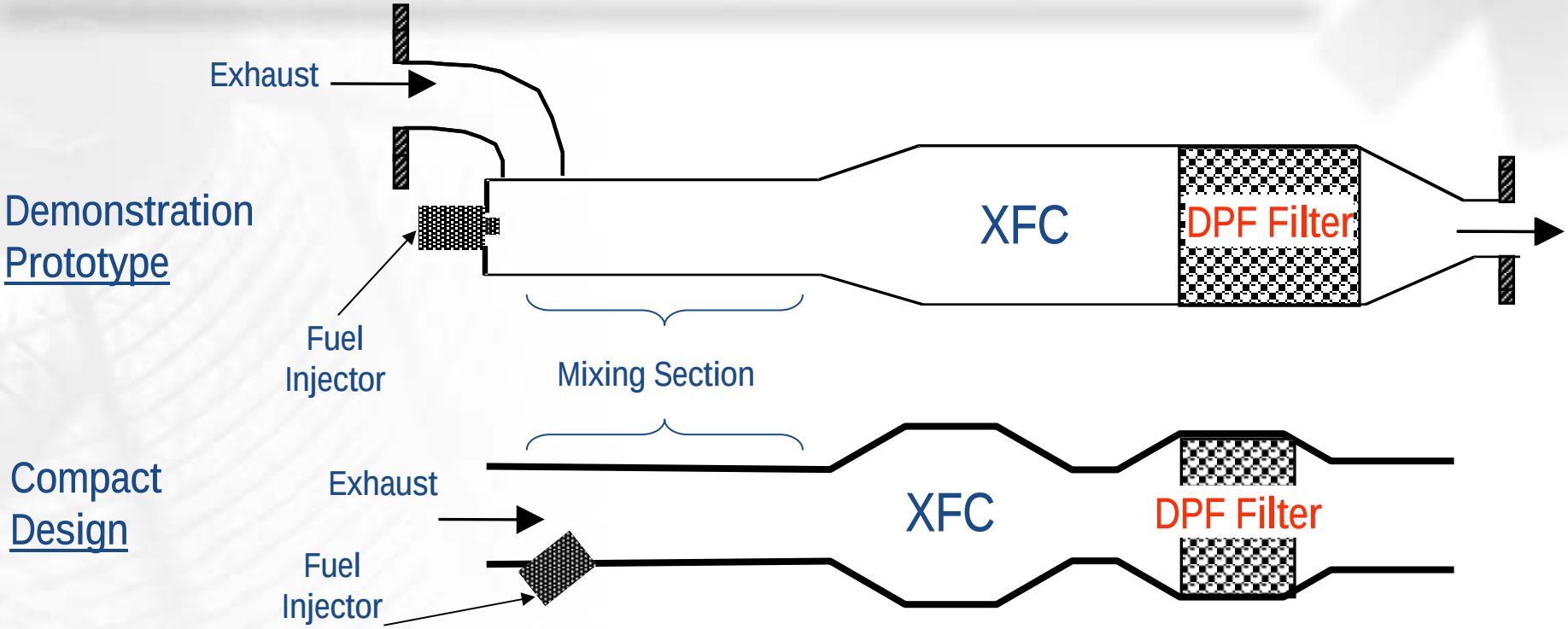
- The Problem…Particulate Matter (PM) Emissions
- Product Concept
- Demonstration Program Objectives
- System Features
- Diesel GENSET Test Stand
- Test Hardware
- DPF Loading
- Engine Test Data
  - XFC™ Thermal Only (no DPF Installed)
  - DPF Regeneration
- Summary

PM Emissions Reduction

In US, PM emission limits reduced by a factor of 10 from 2000 to 2010. 2007 and beyond PM emission limit=0.013 g/bHP-hr (similarly for EU and Japan)



XFC™ Product Concept



What does XFC bring to the party?

- PM filter regeneration through efficient and uniform thermal management
- Extend PM filter life
- Ability to use Cordierite filters will result in cost benefits
- Active at all engine loads

Demonstration Program Objective

Demonstrate active regeneration of catalyzed or non-catalyzed OEM Diesel Particulate Filters (DPF) based on diesel fuel combustion technology in hand.

System Features

- Injection and mixing system that provides uniform fuel air mixture to combustion catalyst.
- Catalytic combustion catalyst providing very uniform heated exhaust gas stream to the PM filter.
- Xonon Fuel Combustor (XFC) to provide the temperature required to initiate complete regeneration of the DPF.
- Prototype system based on developmental hardware scaled to 5.9 liter Cummins engine.

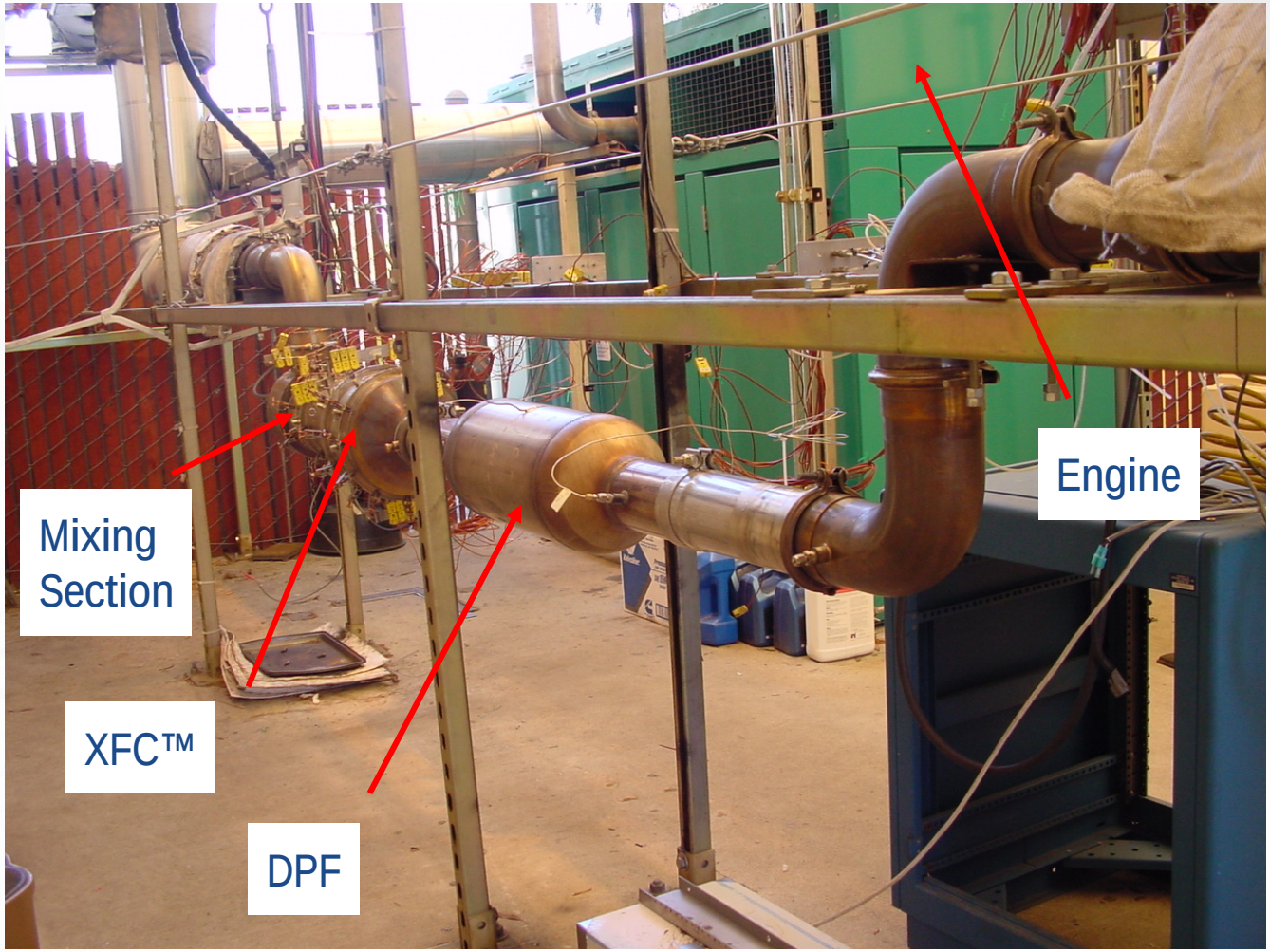
GENSET Test Stand

8.3Liter Cummins Genset

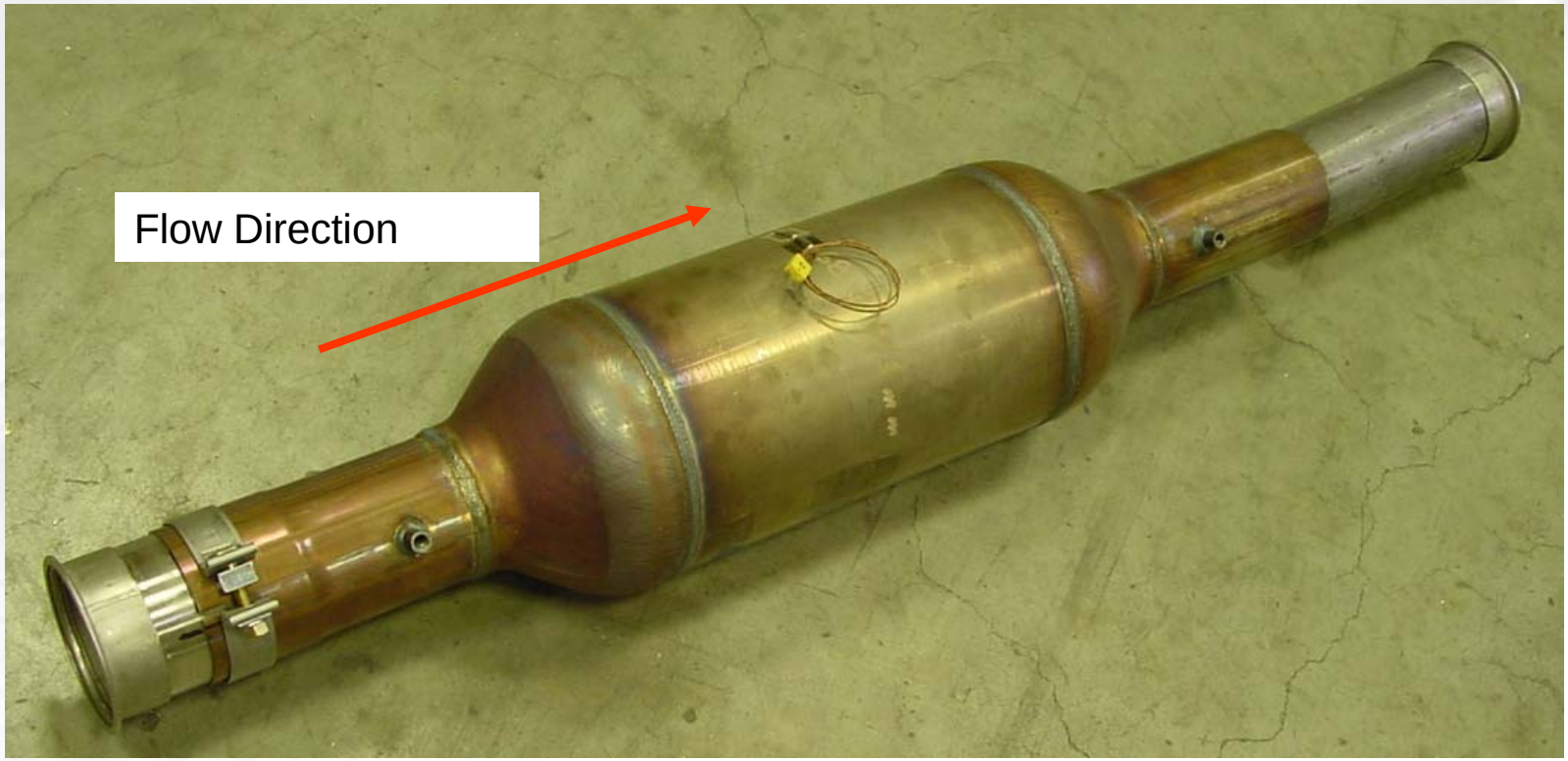
M/N: 6CTA8.3-G2

Output=160kw

RPM=1800 rpm

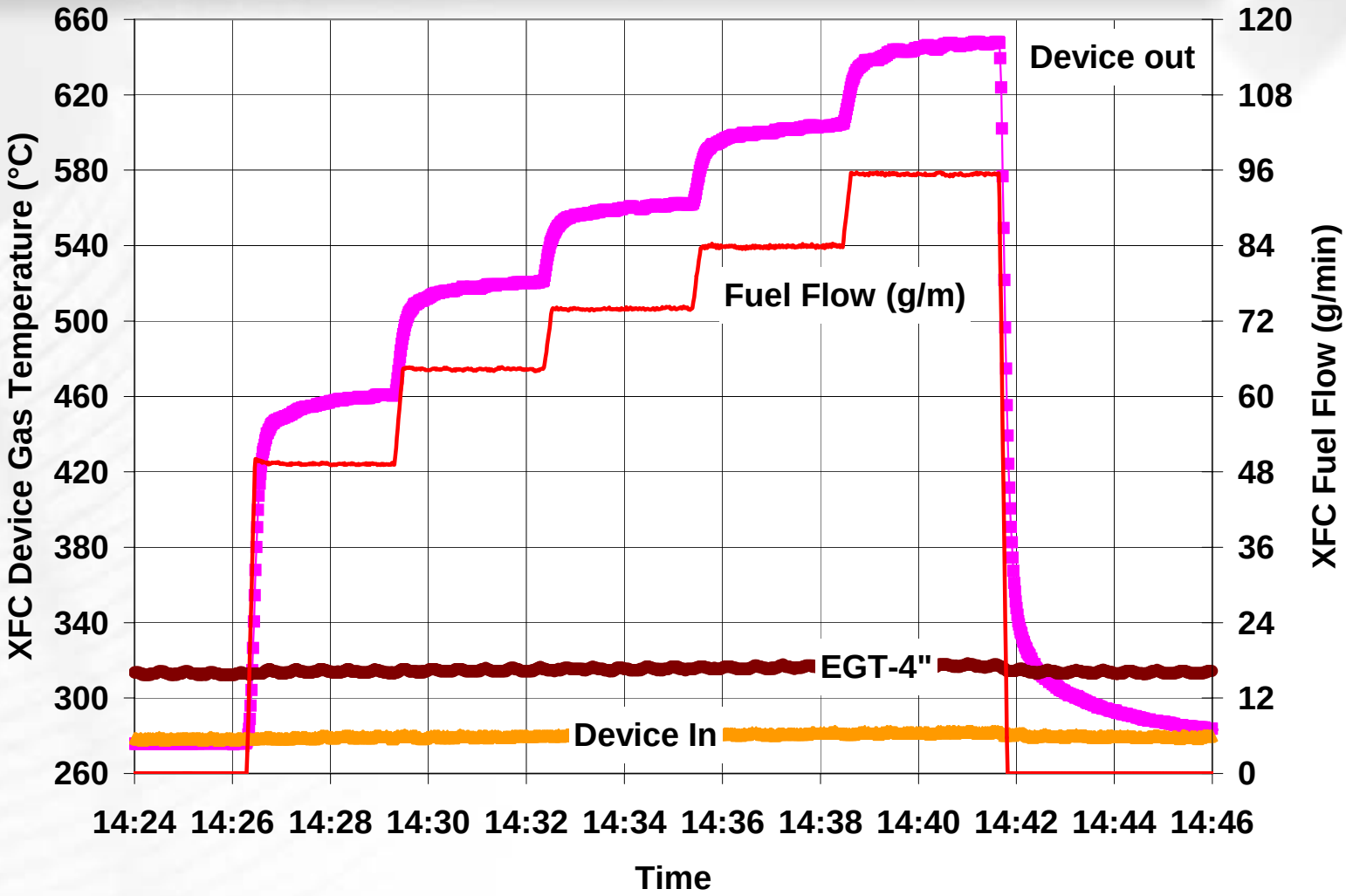


Diesel Particulate Filter



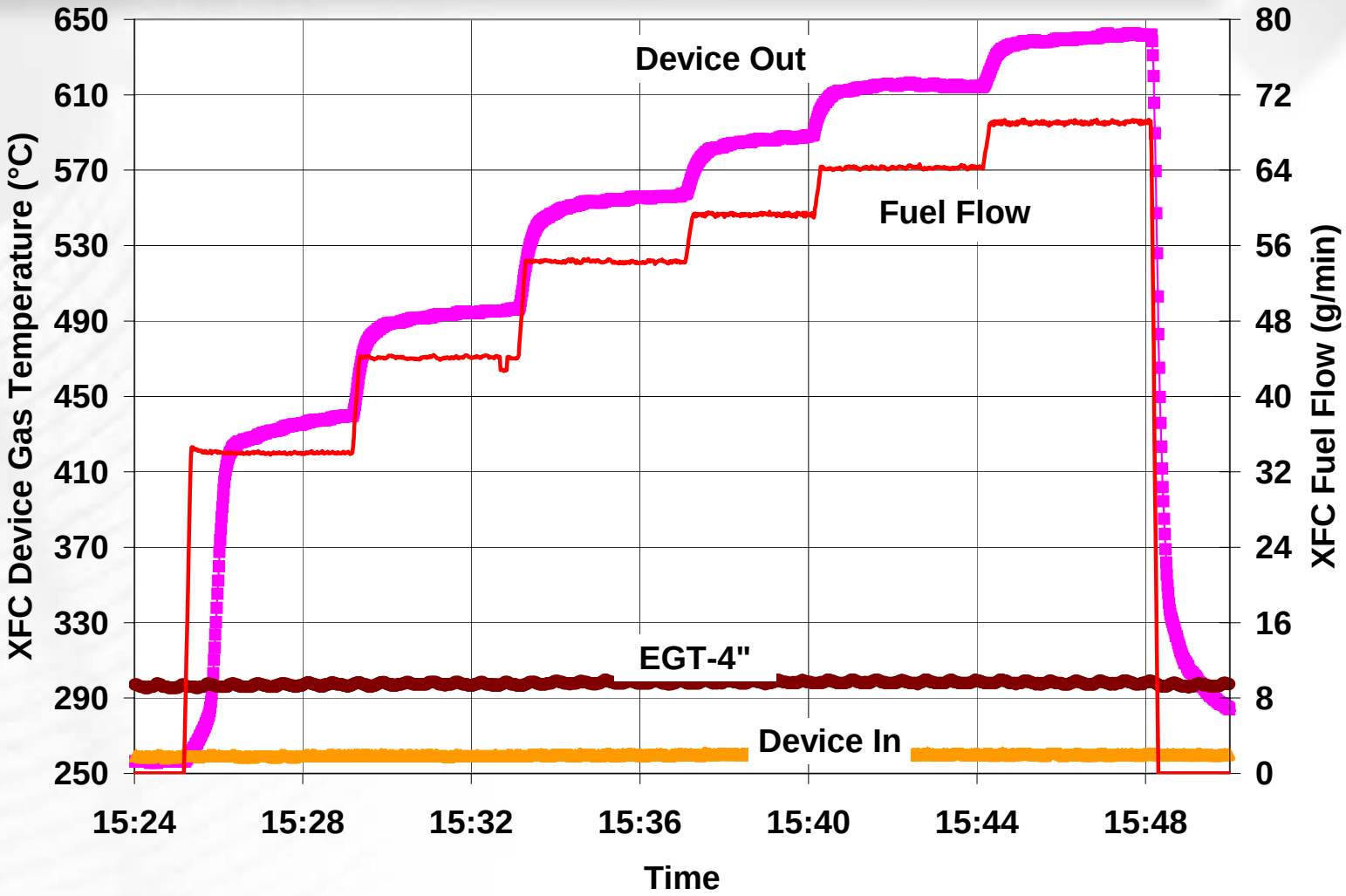
10 Liter, Non-catalyzed, Silicon Carbide

XFC™ Engine Testing: No DPF installed



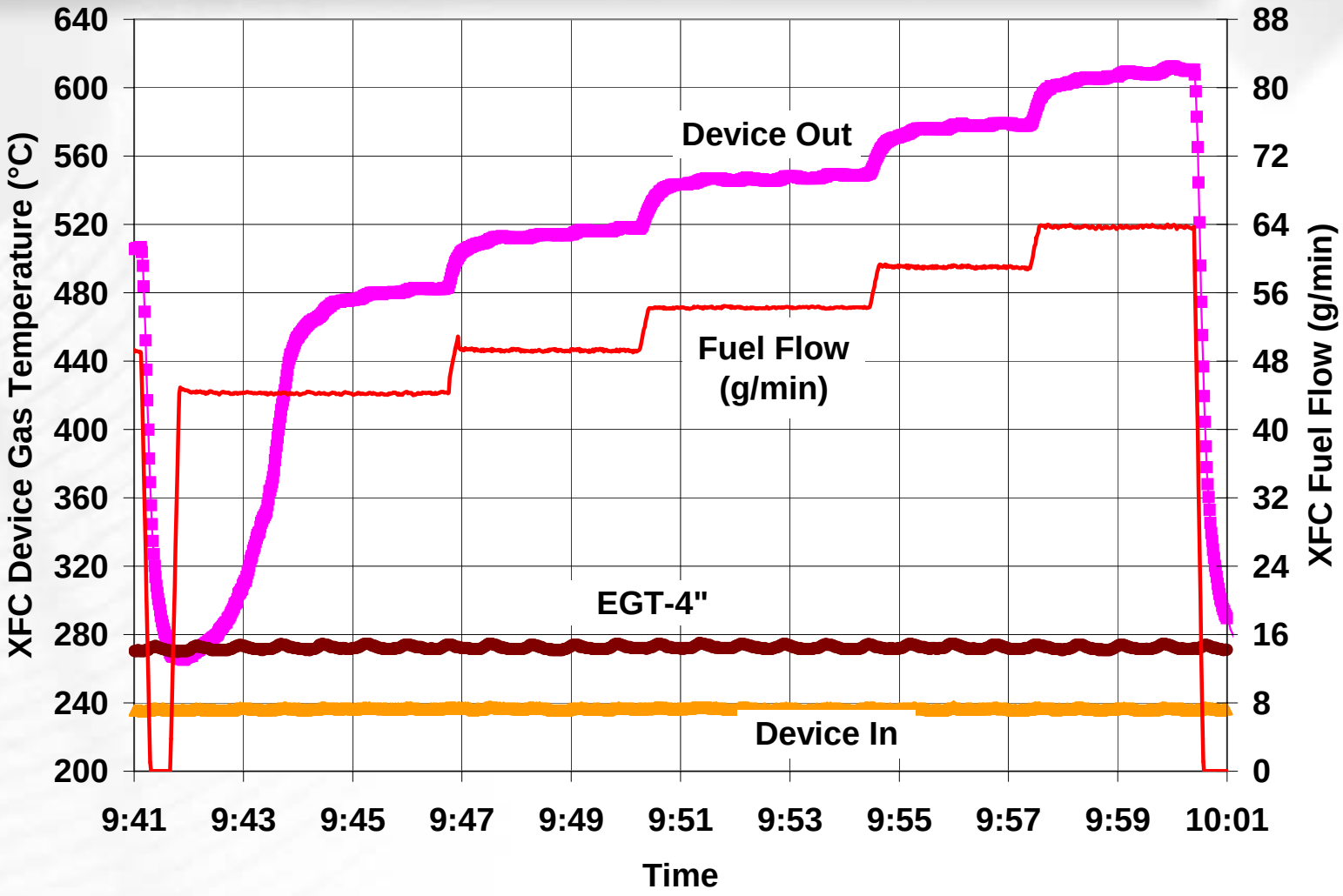
Dodge Ram 70mph: Controlled temperature rise to 650°C inlet to DPF at 270°C inlet to XFC.

XFC Engine Testing: No DPF installed



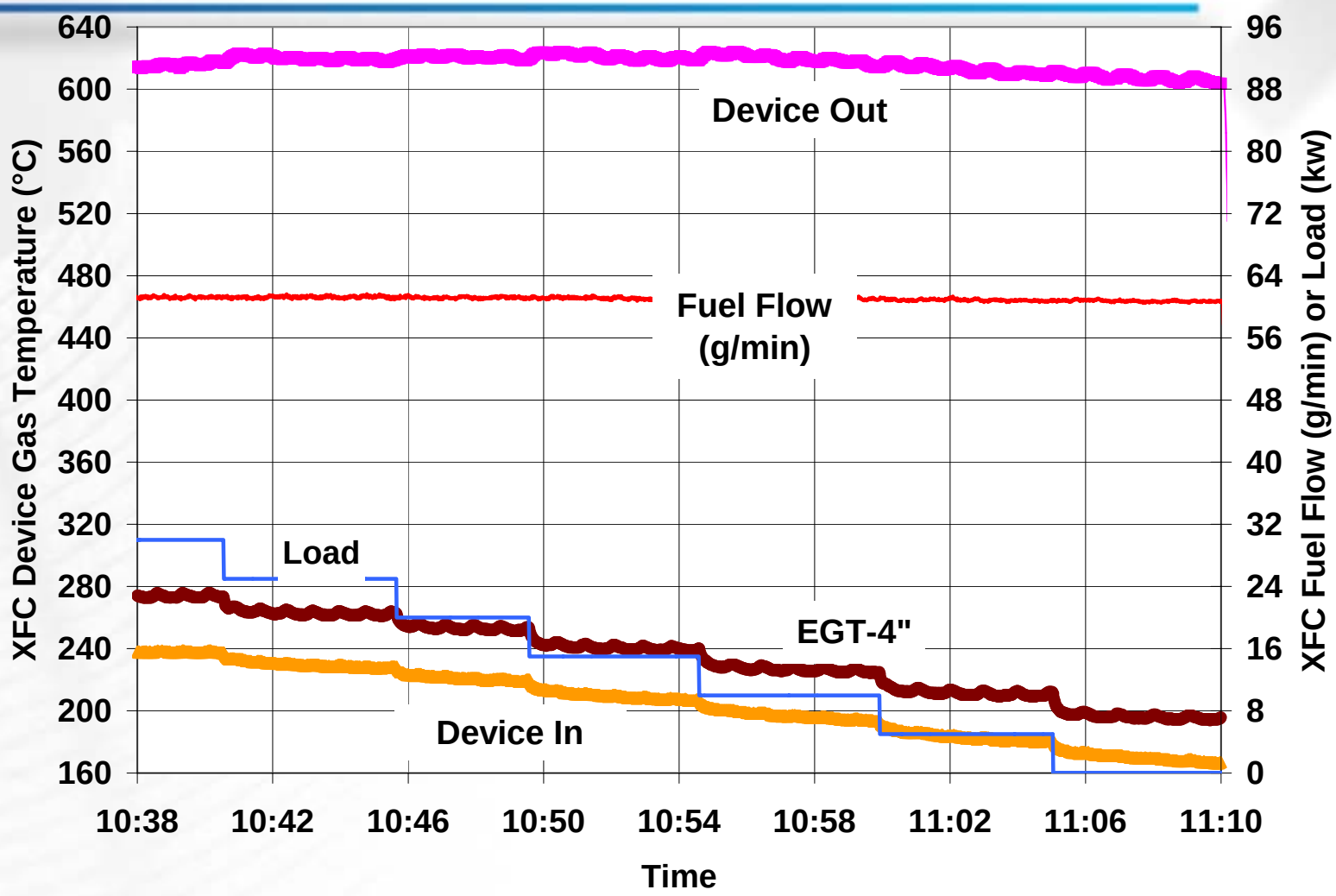
Dodge Ram 55mph: Controlled temperature rise to 650°C inlet to DPF at 255°C inlet to XFC.

XFC Engine Testing: No DPF installed



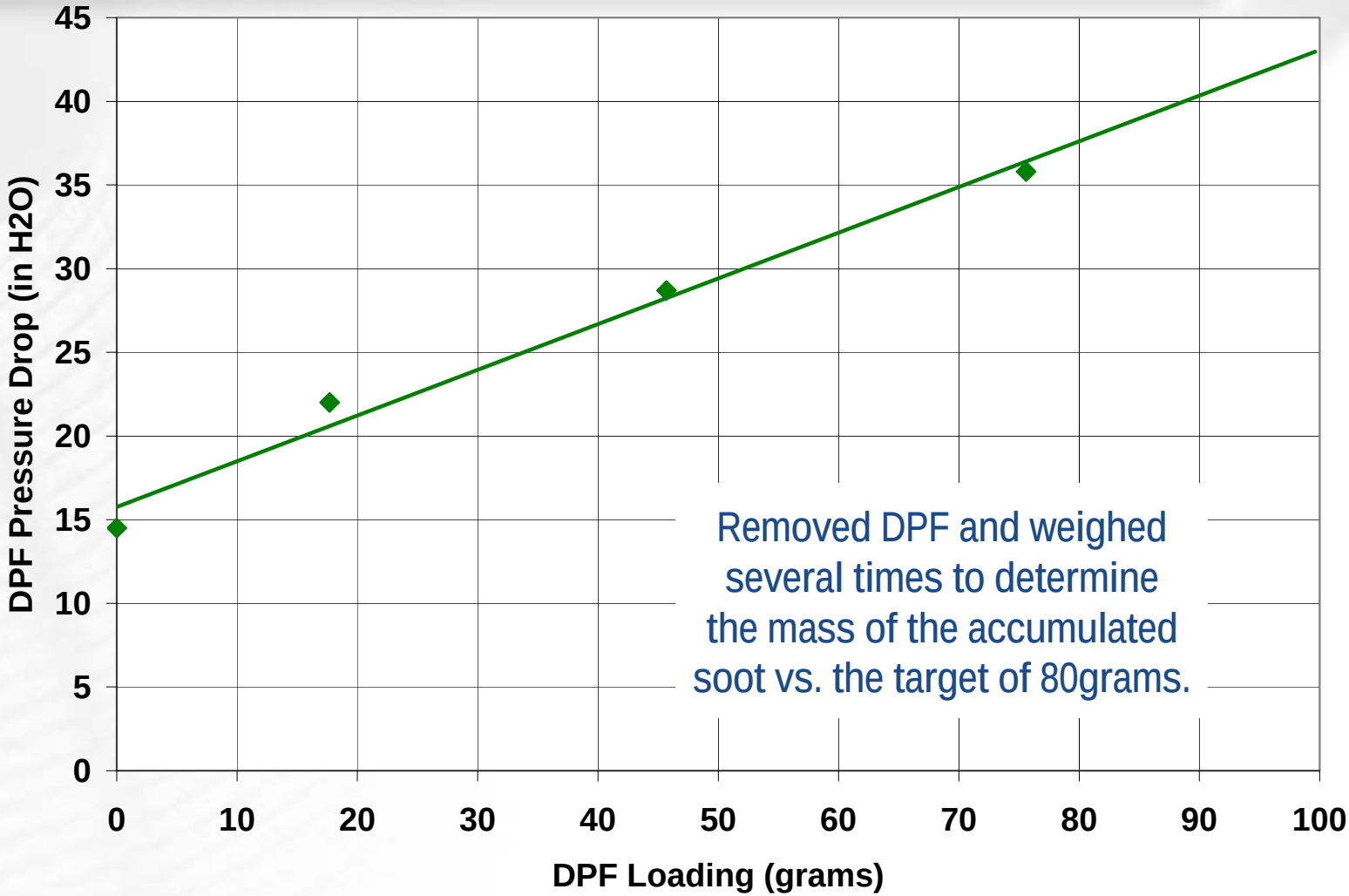
Dodge Ram 40mph: Controlled temperature rise to 610°C inlet to DPF at 236°C inlet to XFC.

XFC Engine Testing: No DPF installed



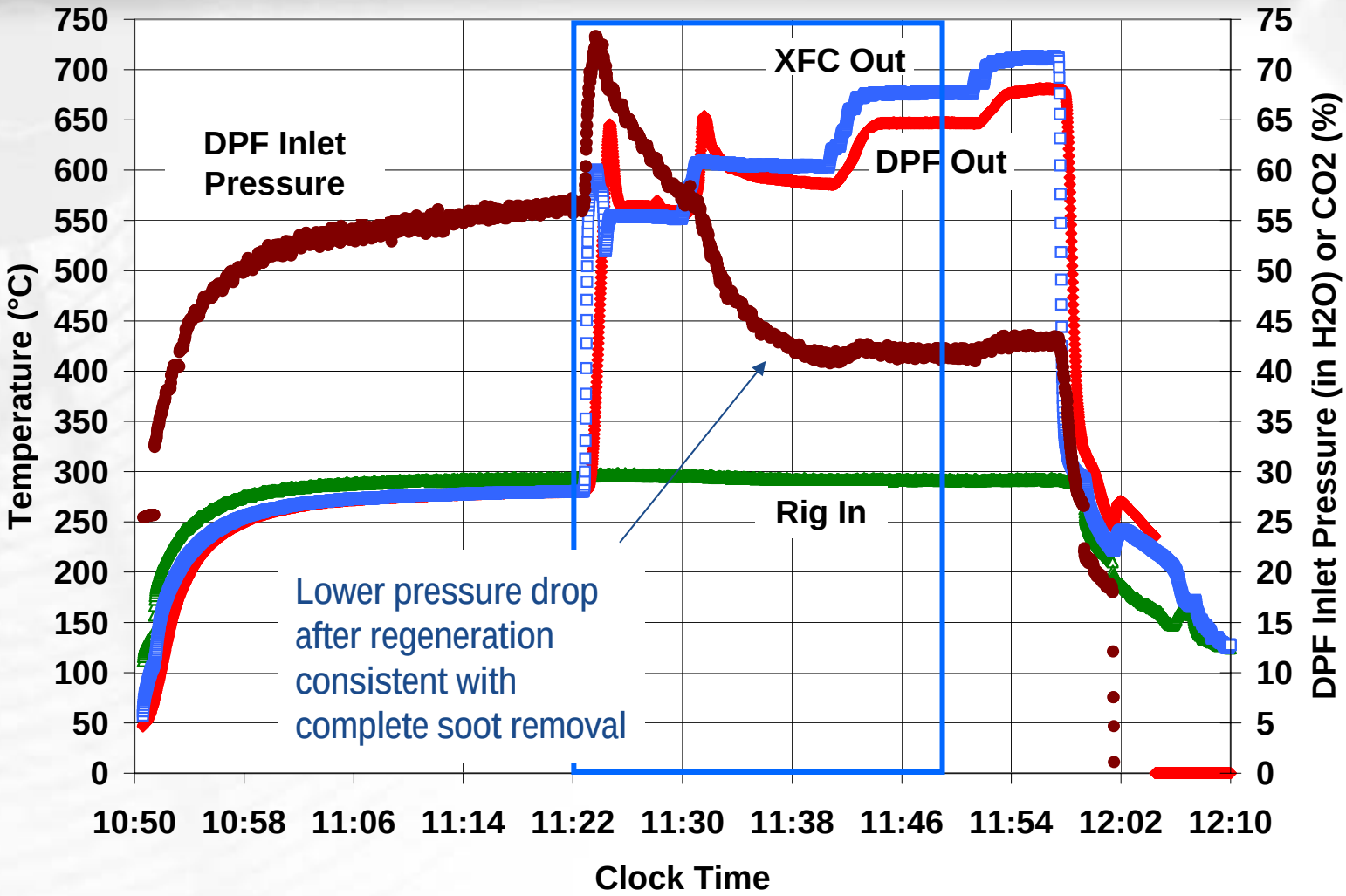
XFC startup at engine exhaust temperatures above 220°C. Once started, ability to operate at exhaust temperatures as low as 180°C

XFC Engine Testing: DPF Loading



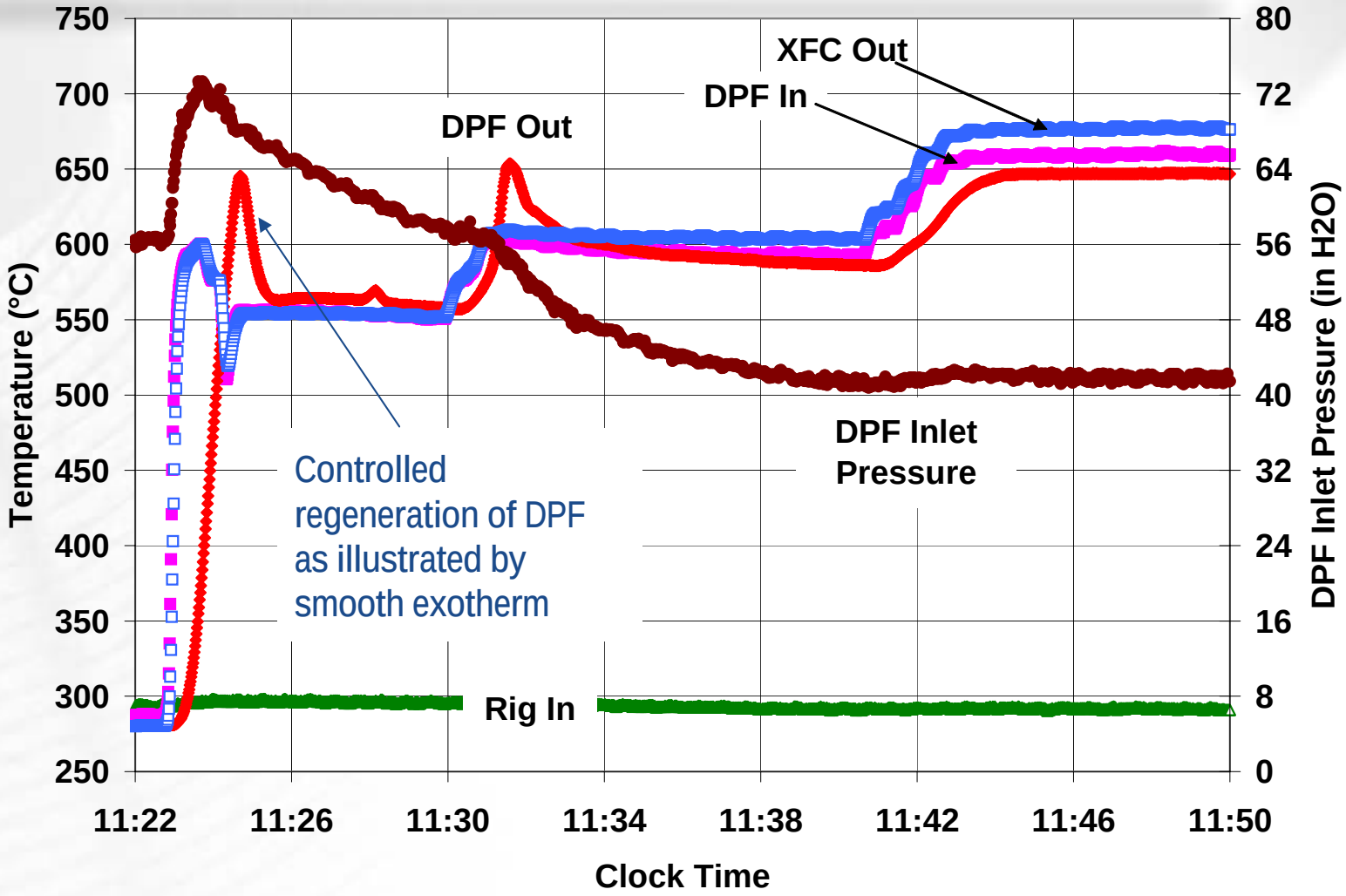
Loaded DPF with ~75 grams of soot

XFC Engine Testing: DPF Regeneration



DPF regeneration initiated at 550°C and was complete at 600°C

XFC Engine Testing: DPF Regeneration



Temperature rise across DPF: 100°C at 550°C and 50-60°C at 600°C

Summary

- Successful demonstration of XFC™ technology
  - Ability to controllably produce the required temperature to regenerate a Diesel Particulate Filter
  - Based on Gas Turbine catalyst development and design experience as applied to CESI's Xonon Fuel Processor (XFP™) for Diesel NOx Emissions Reduction
- Successful demonstration of DPF regeneration
  - Highly controllable process
  - Uniform temperature field exiting XFC™ (+/-25°C) with lower variations entering DPF
  - Complete removal of accumulated soot at average temperatures lower than typical with a non-catalyzed DPF – weight after regeneration equal to weight prior to
- Identification of several value added system features
  - Ability to use non-catalyzed or partially catalyzed DPF
  - Use of lower cost substrates given the controlled and uniform exotherm in DPF
  - Active regeneration ("on-demand") within a large portion of the engine operating duty (at device inlet temperatures as low as 200-220°C)
  - Minimal fuel penalty and hydrocarbon breakthrough

What's Next?

- System design for DPF regeneration
  - Fits into undercarriage space
  - Low cost system
  - Low pressure drop
- Transient operation
- Control strategy
- Vehicle demonstration/evaluation

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