PRESENT AND FUTURE EMISSION PROSPECTS FOR DIESEL AND NATURAL GAS FUELED MARINE ENGINES

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Emerging NOx Reduction Technologies

Introduction

- Current marine emissions standards
- Other industry standards
- Current NOx reduction technologies
- Emerging NOx reduction technologies
- Natural gas combustion processes
- Challenges for natural gas as a marine fuel

Emerging NOx Reduction Technologies

Emissions Forecast

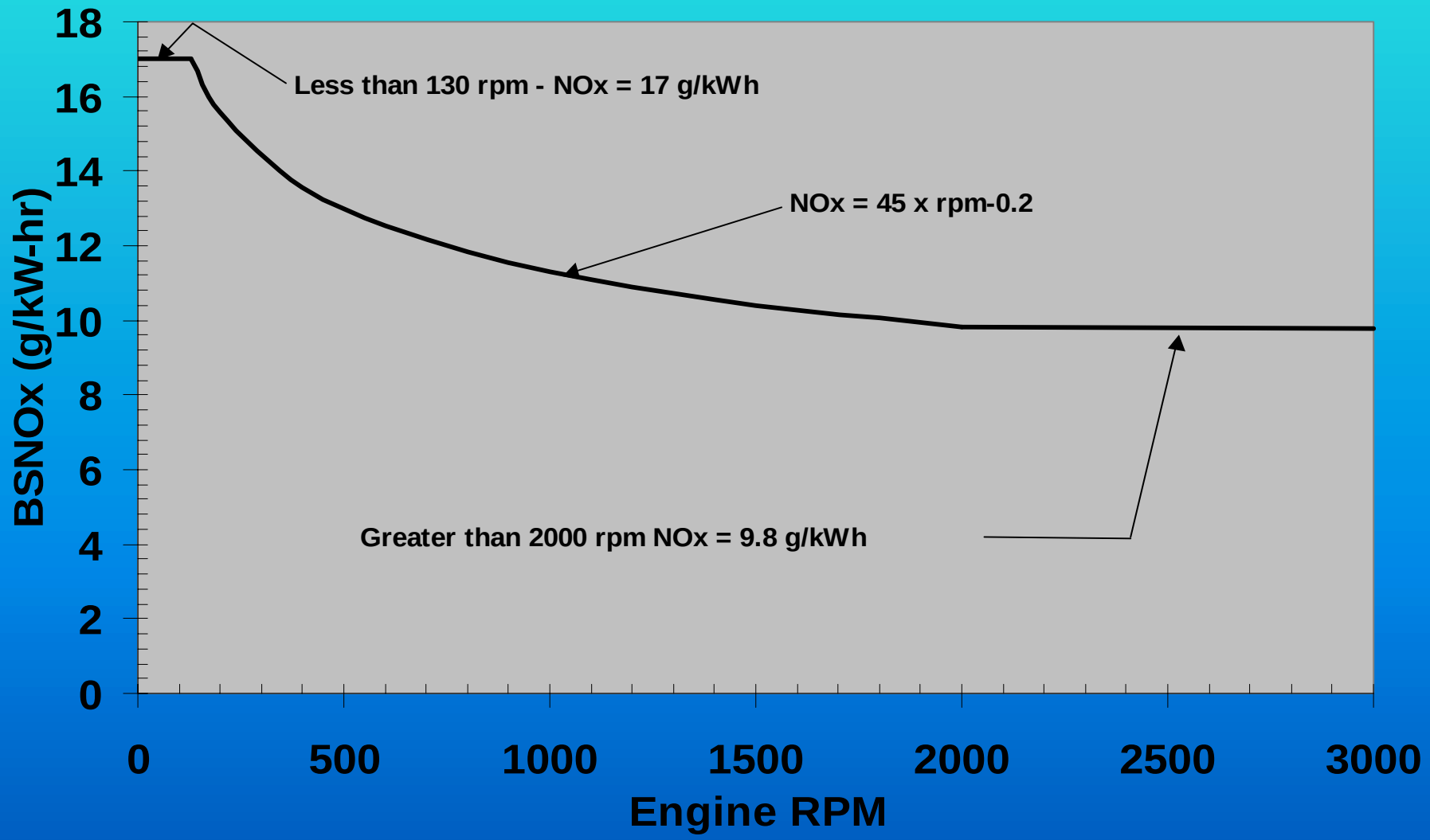
Today

Partly Cloudy

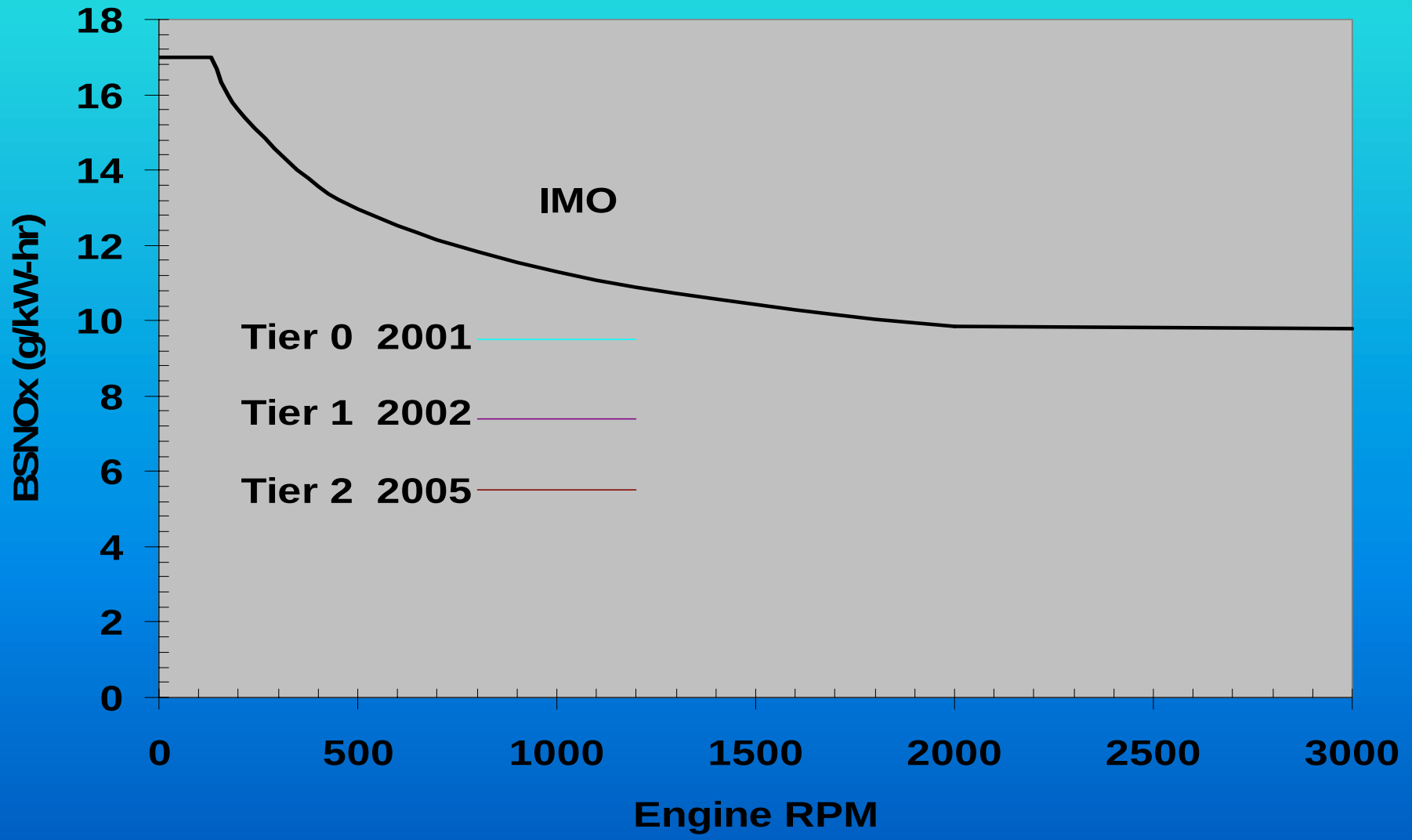
Tomorrow

Rain

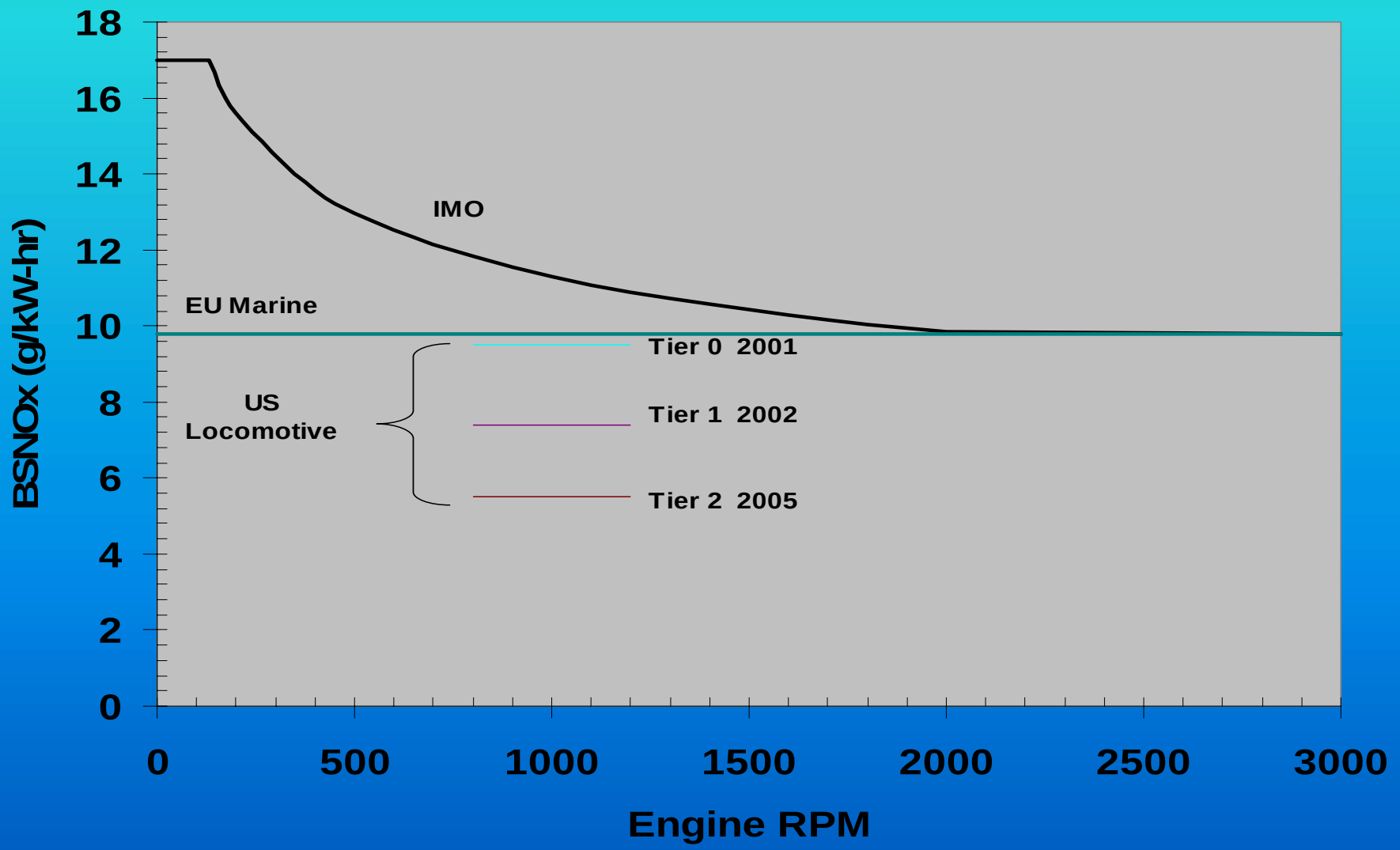
IMO NOx Emissions Standard (MARPOL ANNEX VI)



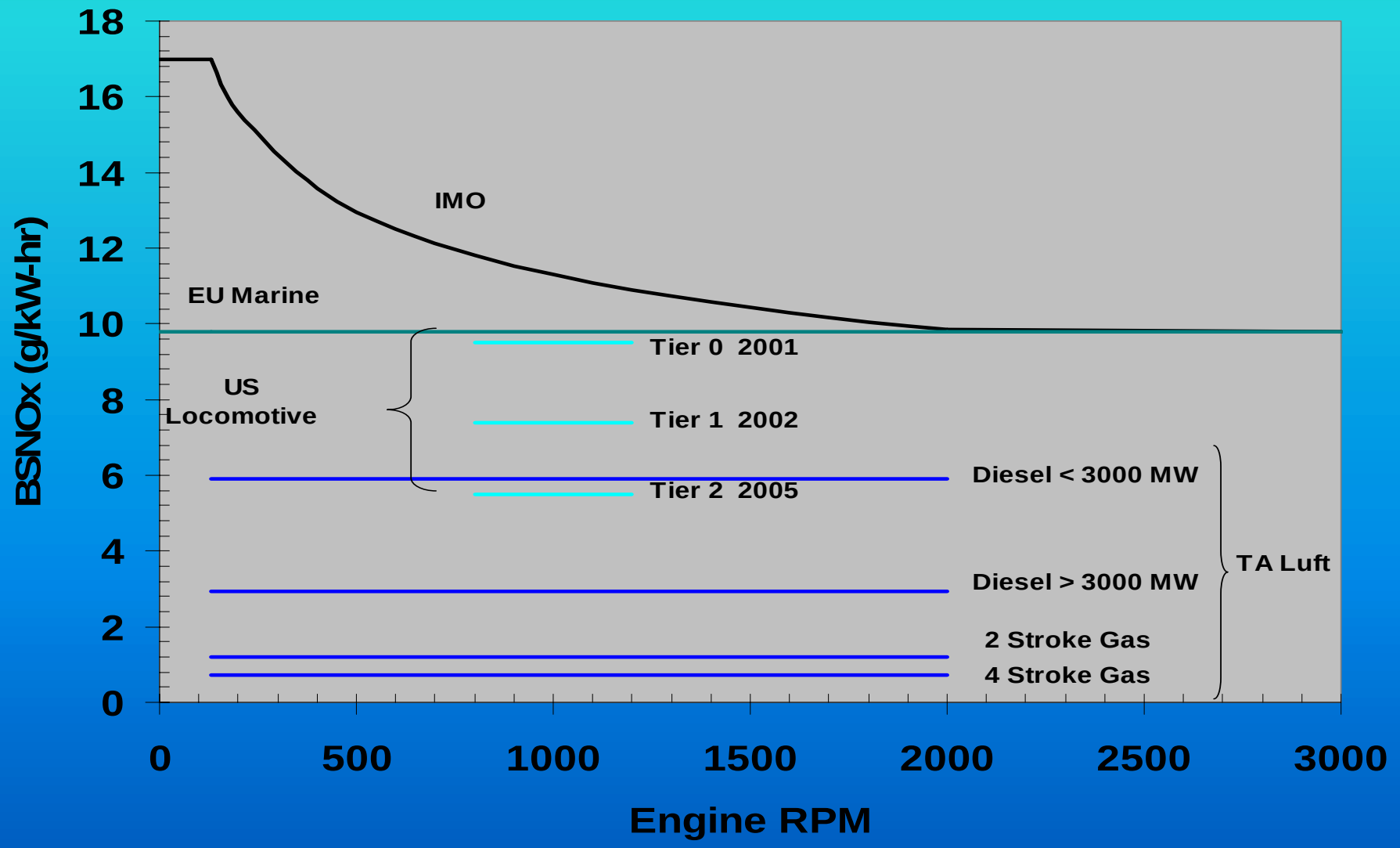
US EPA Locomotive NOx Emissions Standard



European Union Marine NOx Emissions Standard



TA Luft
NOx Emissions Standard



Current NOx Reduction Technologies

Precombustion	Engine Modification	Post Combustion
Air Cooling	Alteration of Combustion Process	SCR
Humidification	Injection Timing Retard	
Water/Fuel Emulsion	Injection Rate Shaping	
Fuel Quality	Compression Ratio	
	Turbulence	
	Increased Air Density	
	Low Charge Air Density	
	High Charge Air Pressure	
	EGR	

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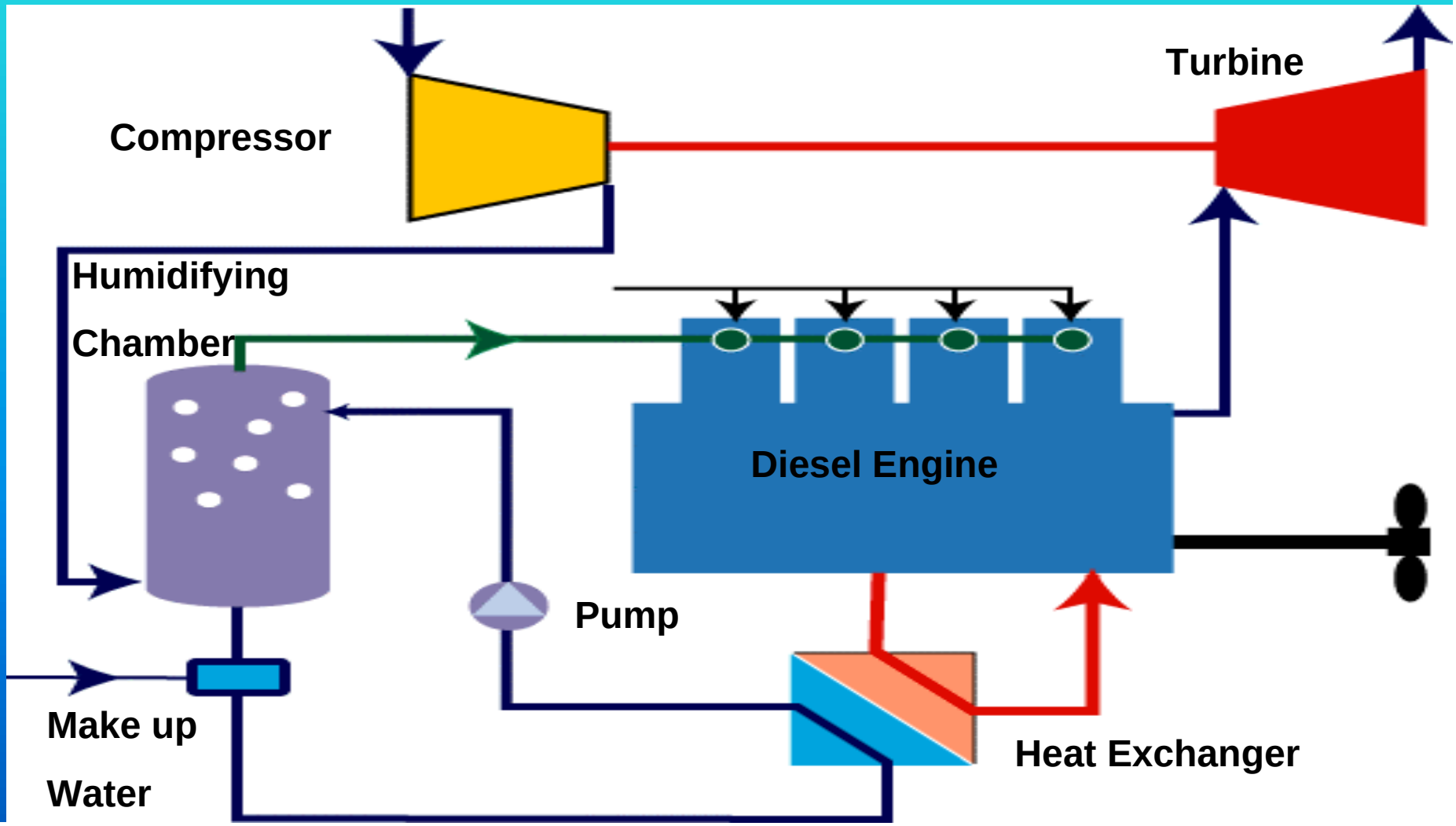
Precombustion	Engine Modification	Post Combustion
Natural Gas	Electronic Fuel Injection Control	Lean NOx Catalyst
Bio-diesel Fuel	HCCI	Non-Thermal Plasma
DME	HAM	
	Direct Water Injection	

Emerging NOx Reduction Technologies

SEMT - Munters HAM System



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SEMT - Munters HAM System

Performance Results

- **High Efficiency NOx Reduction: 70% at full load and more at low loads**
- **Very low operating cost: sea water can be used**
- **Simple and self-control system**
- **Engine is cleaner: less carbon deposits**
- **Easy maintenance**
- **Decrease in engine thermal stresses: valve and exhaust gas temperatures reduced**
- **Energy needed by the process comes from waste heat**

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SEMT - Munters HAM System

Comparison with SCR

- **Overall dimension and weight are reduced**
- **Much lower operating cost (approx.. $0.01/kg NOx vs. $0.29/kg NOx**
- **No risk of secondary emissions (i.e., ammonia slip)**
- **Good NOx reduction at low loads**
- **Not affected by sulfur in fuel**
- **Not sensitive to fuel quality**
- **No additional cargo or storage tanks**
- **Initial installation higher (approx.. $80/kW vs.. $55/kW**

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Advantages of Natural Gas Fuel

Greatly Reduced Emissions of NOx, Smoke, Particulate and Sulfur

Lower Cost Fuel

Reduced Ring and Liner Wear

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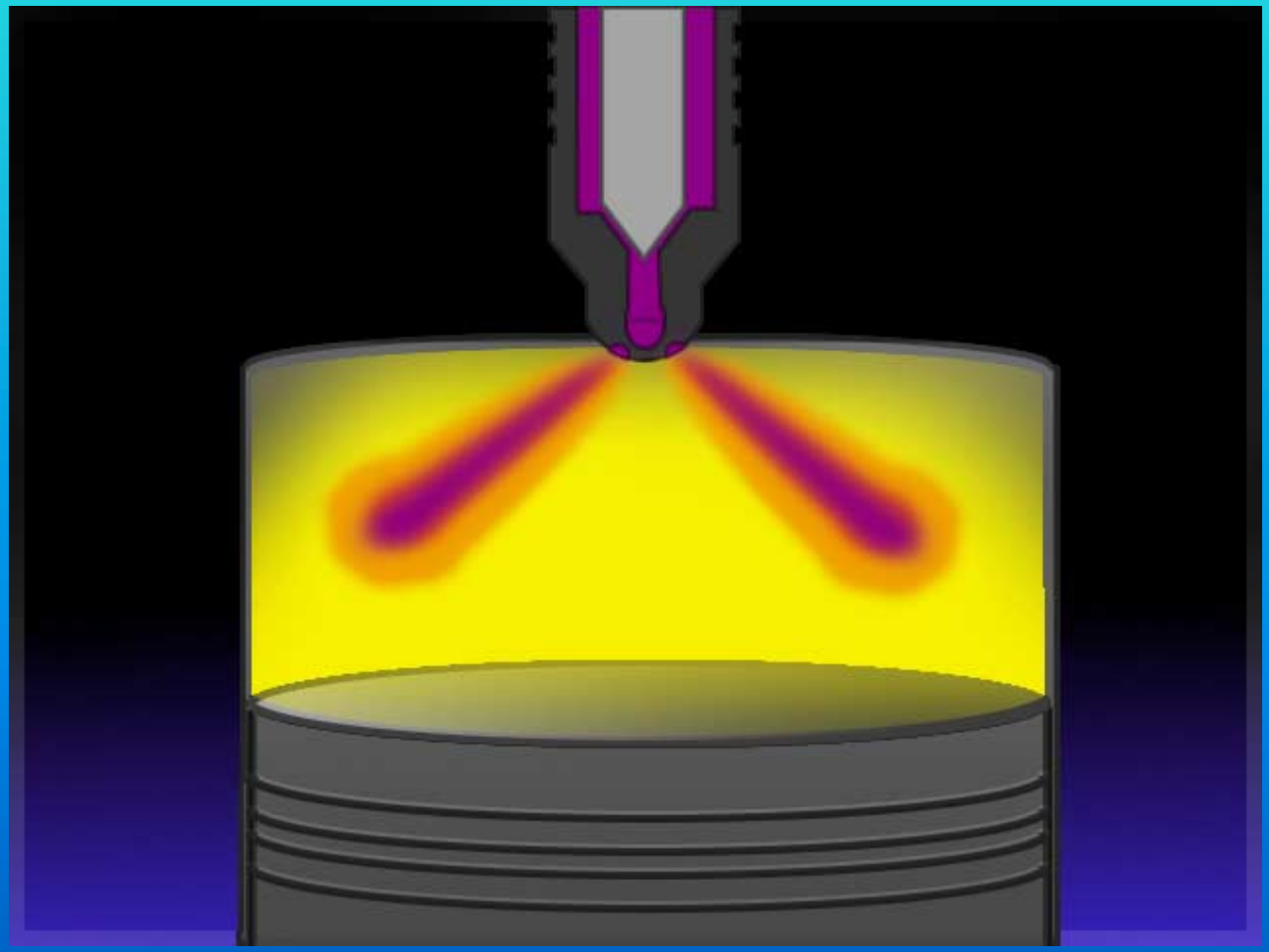
Diesel



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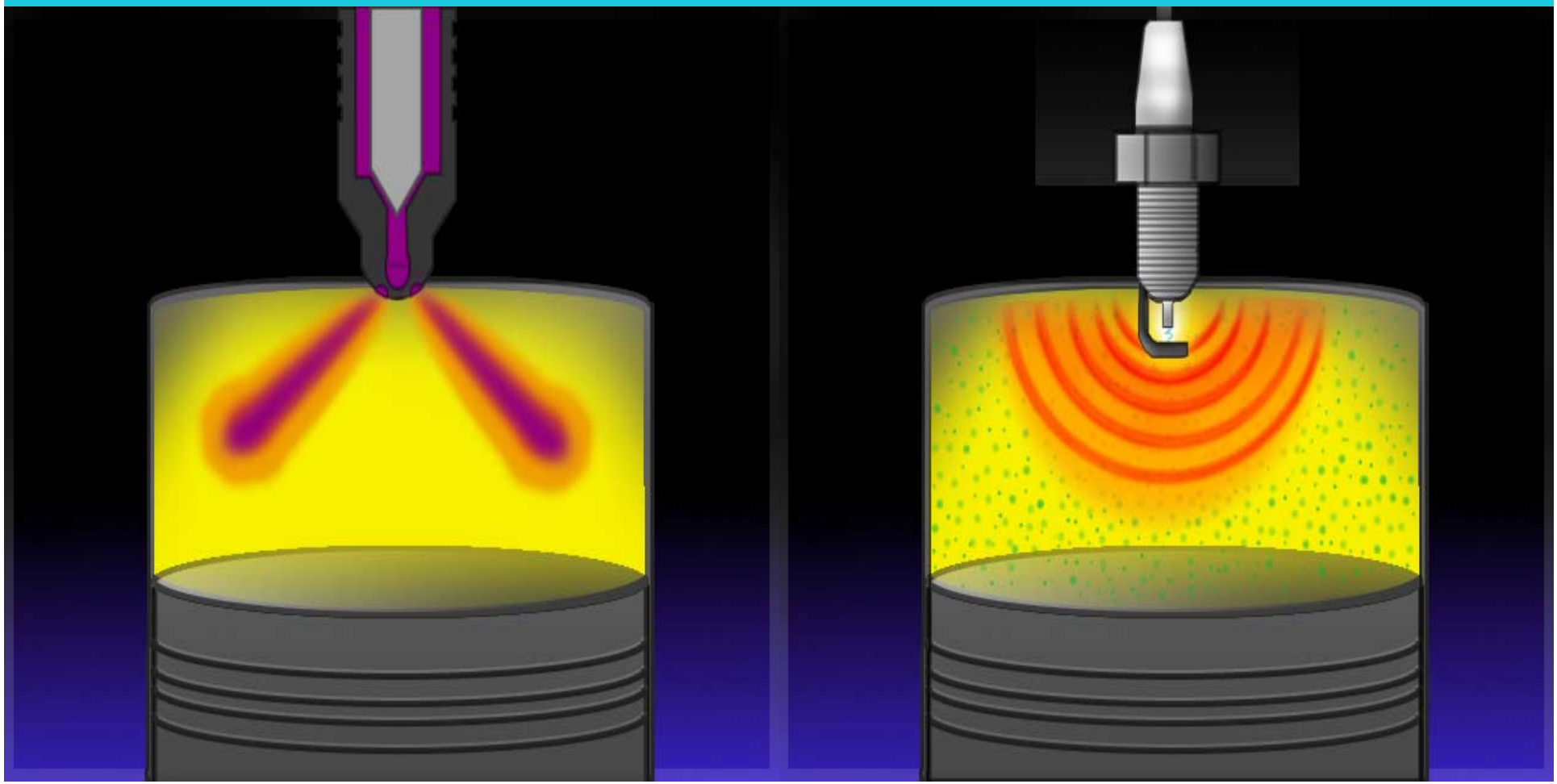
Diesel

Open Chamber Spark Ignited Natural Gas



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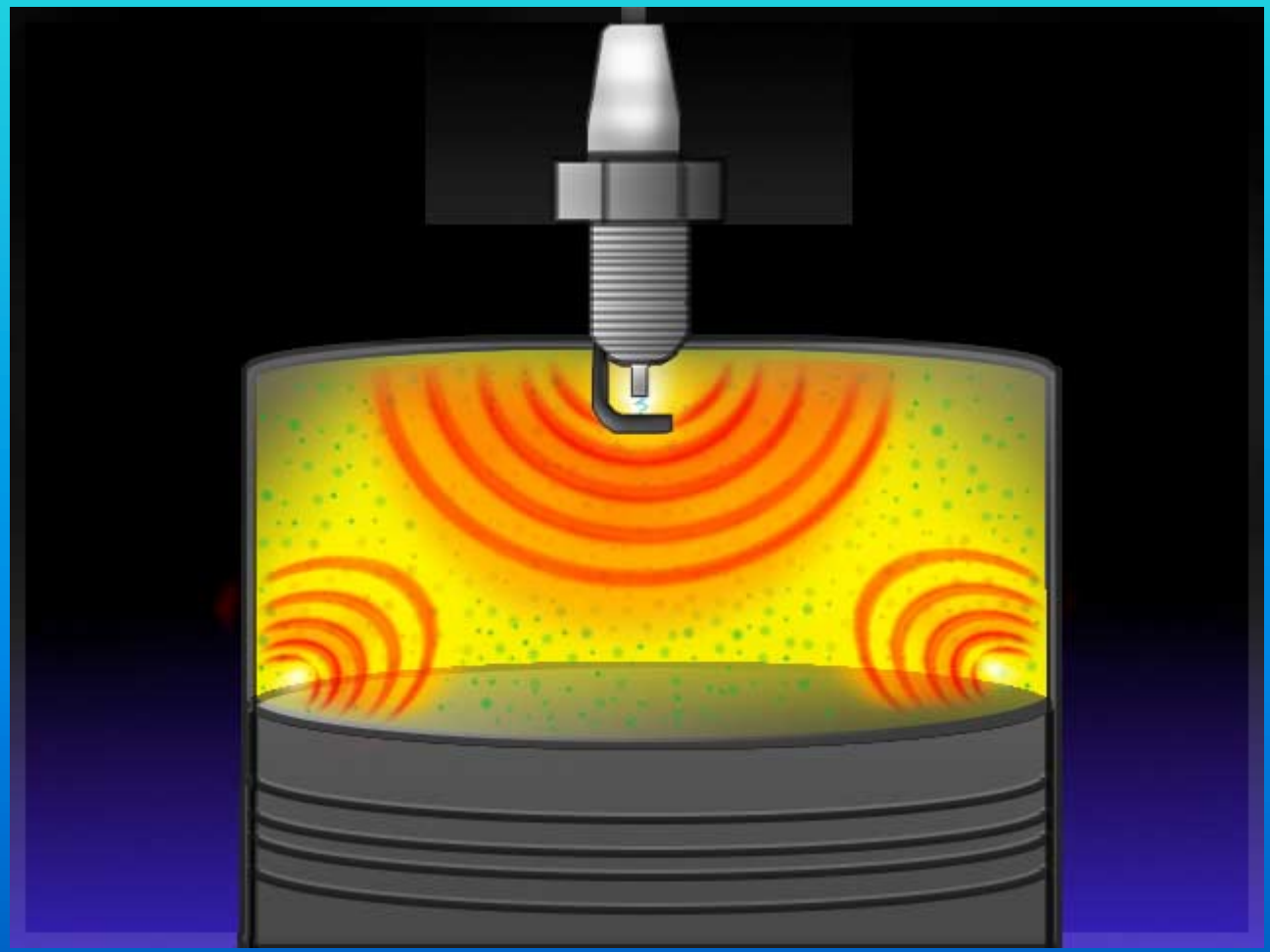

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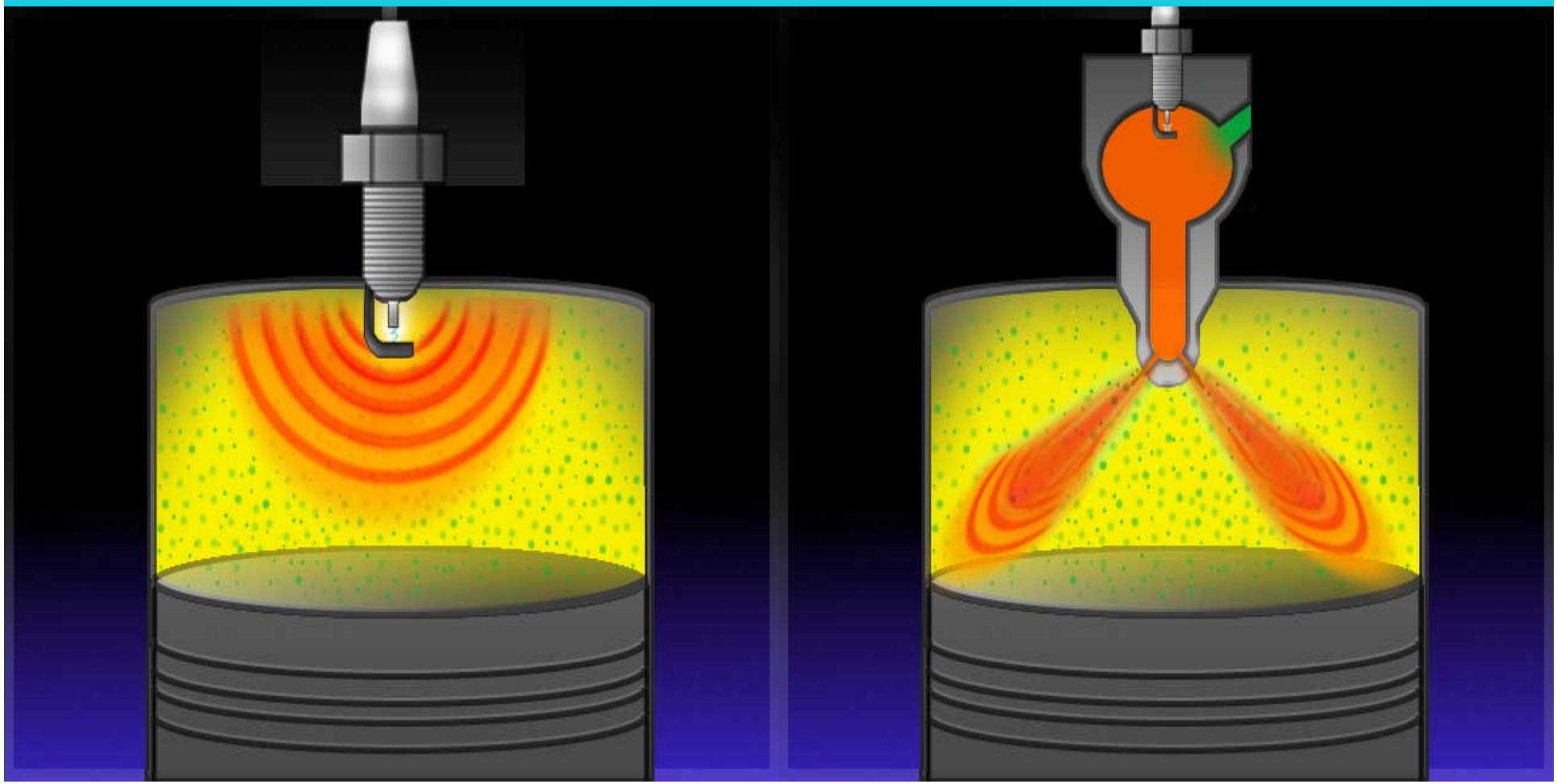
Open Chamber Spark Ignited Natural Gas

Prechamber Spark Ignited Natural Gas



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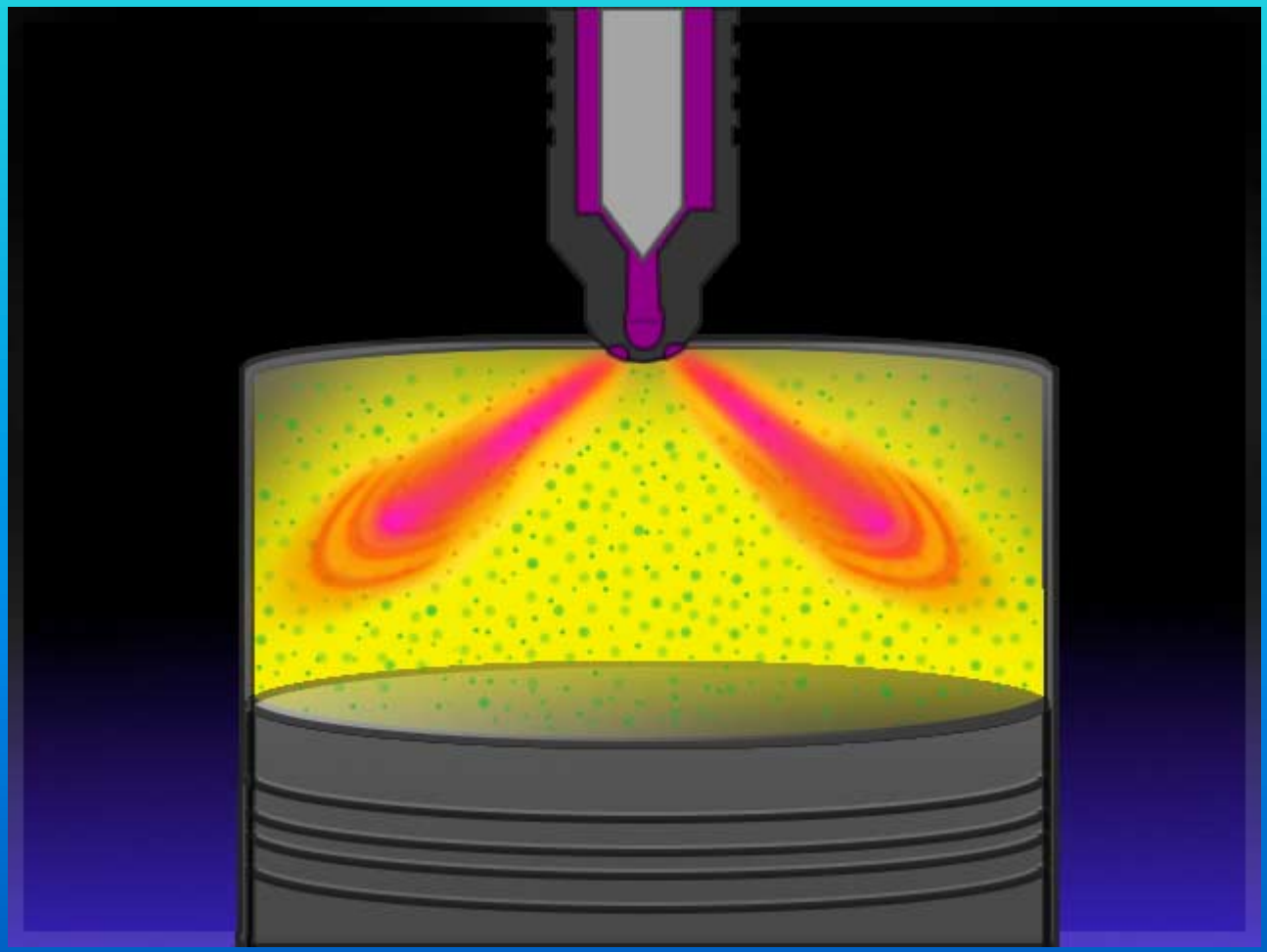
Conventional Dual Fuel



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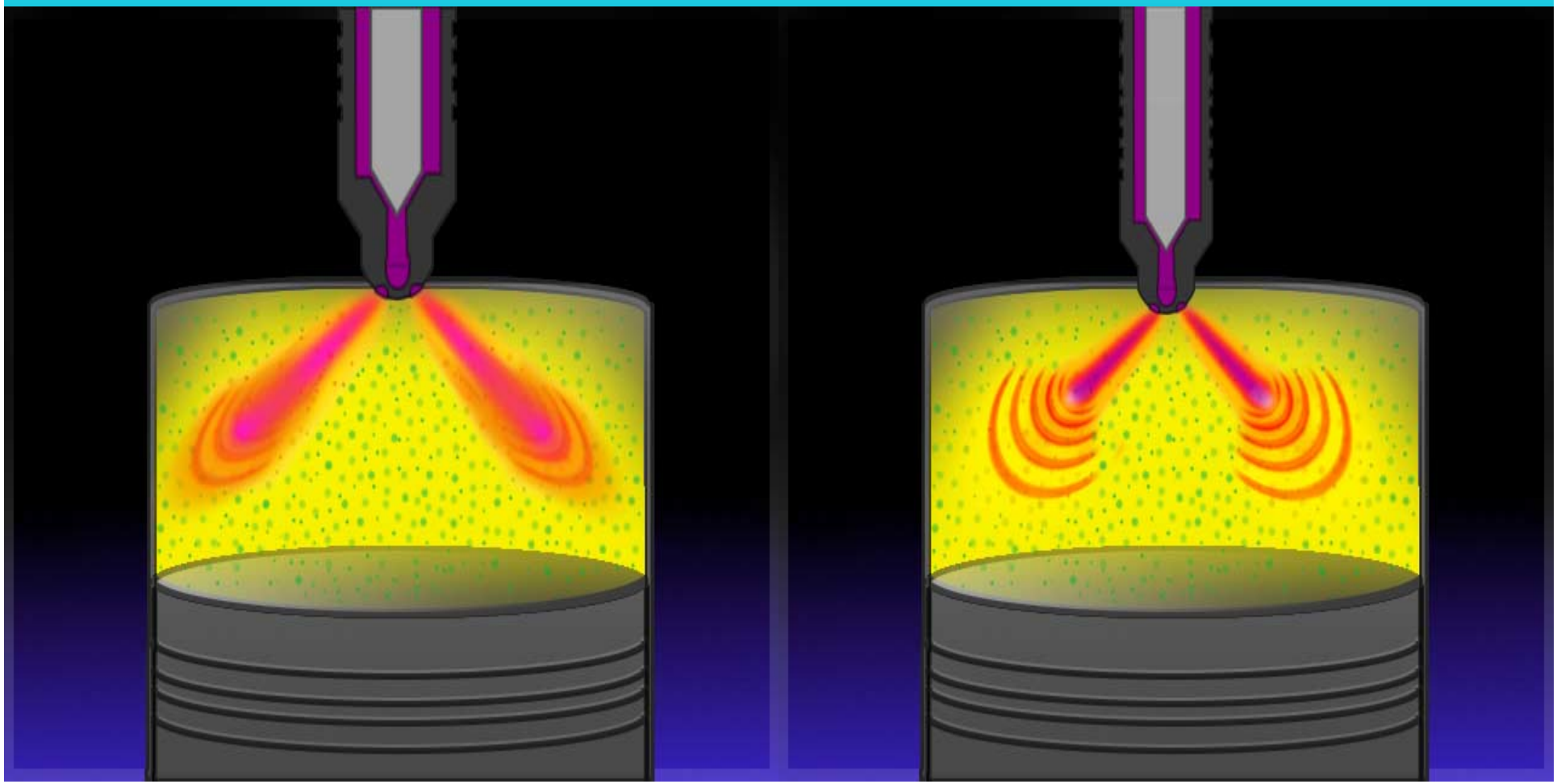
Conventional Dual Fuel

Micro Pilot Open Chamber Dual Fuel



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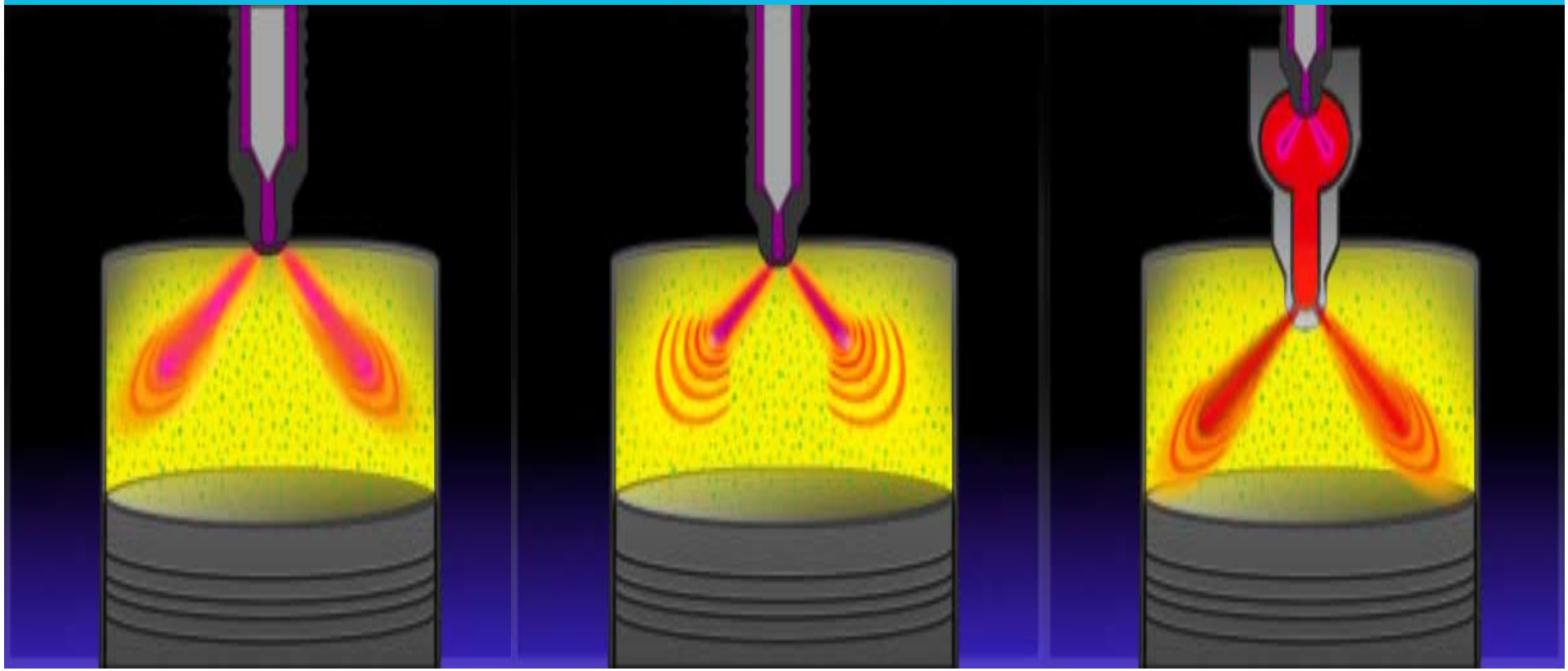
Conventional Dual Fuel

Micro Pilot Open Chamber Dual Fuel

Micro Pilot Prechamber Dual Fuel



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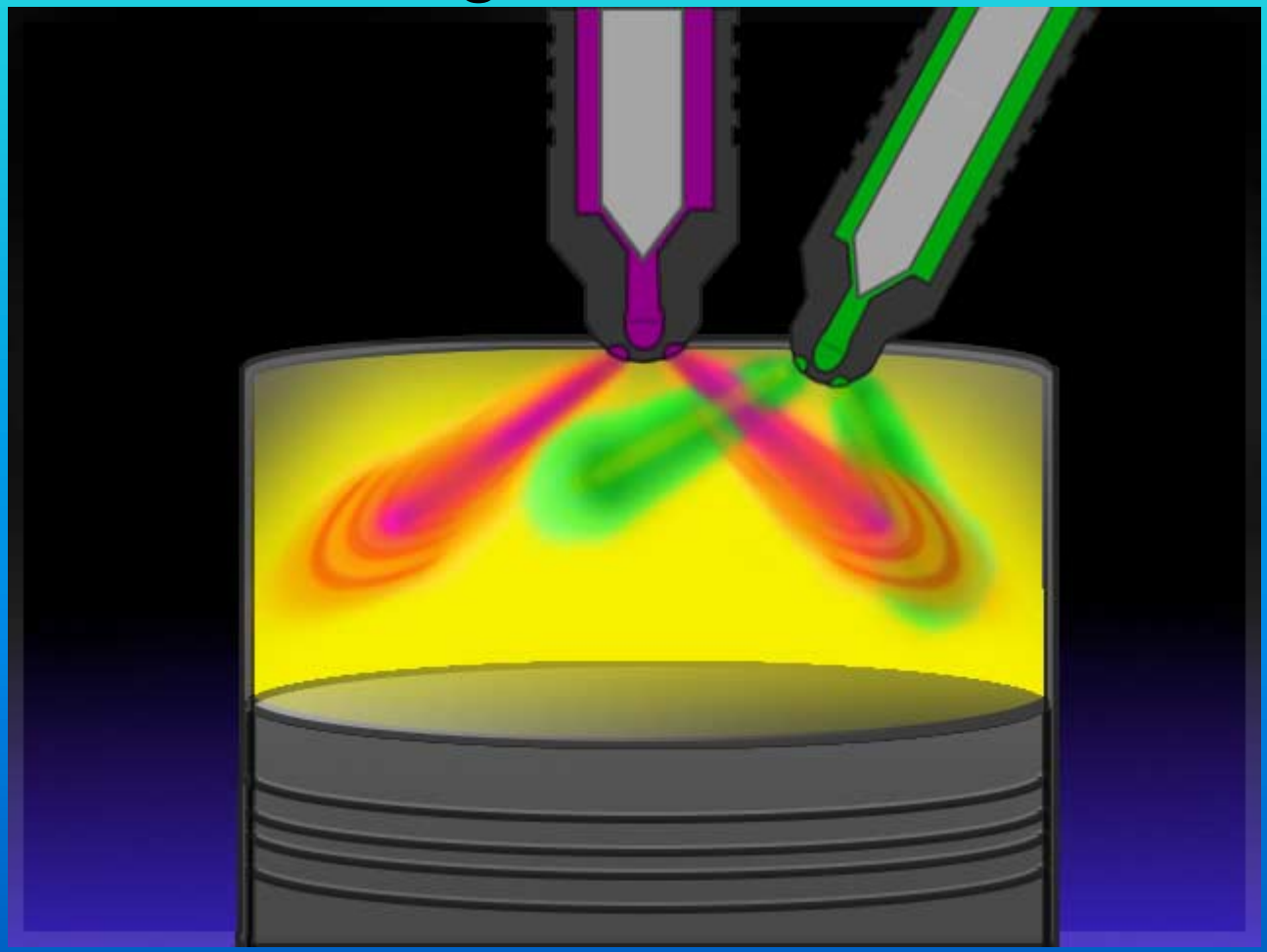
High Pressure Gas Injection
Pilot Ignited Dual Fuel



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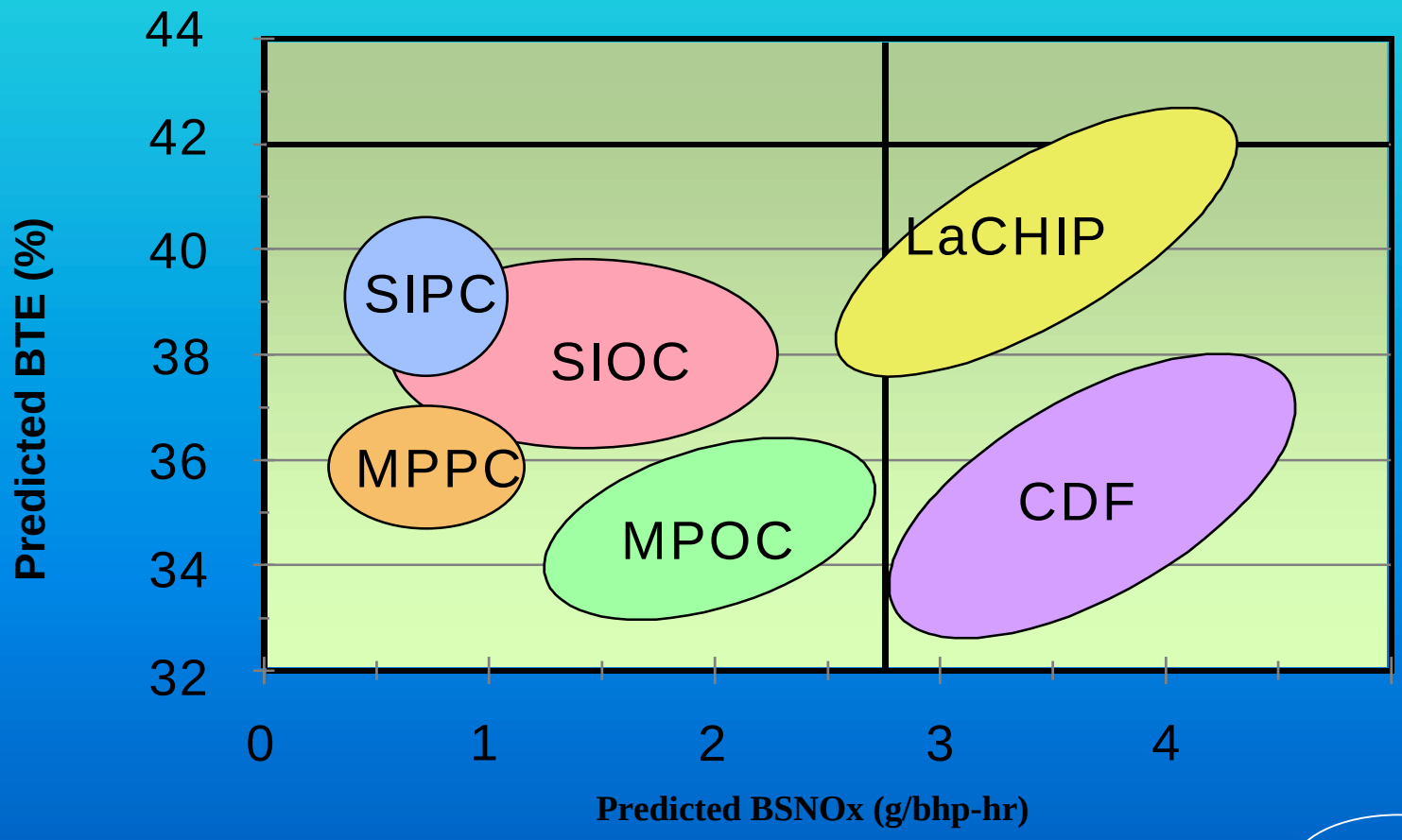

SwRI

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Challenges for Natural Gas as a Marine Fuel

	Definitely Not	No	Maybe	Yes	Definitely Yes
Safety		X			
Environmental Concerns	X				
Infrastructure			X		
Variable Speed		X			
Mobility		X			
Mindset			X		

Emerging NOx Reduction Technologies

Conclusion and Summary

- **Most diesel engines can meet IMO Standard by simple engine or system modifications, albeit with some economic penalty.**
- **More restrictive regional and/or future global emission standards may be expected.**
- **New innovative “bolt on” emissions reduction systems are starting to emerge.**
- **Natural gas offers significant advantages over other technologies in terms of both emissions reductions and operating cost.**