Navy Marine Engine Exhaust Emissions Reduction Prog. and Pilot Retrofit Program

Presented by:

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Overview

- **Marine Eng. Exhaust Emissions – Big Picture**
- **Navy Marine Eng. Ex. Emissions Reduction Prog.**
  - Compliance policy/strategy, intro. of compliant engines, inventory definition, and technology development/insertion
- **Navy Pilot Retrofit Program**
  - Intent and scope
  - Technologies selected for further evaluation
    - Target population and operating conditions
    - Selection process and description of technologies
    - Cost / benefit comparison
  - Test plan
    - Lab test process and projected progression
    - Shipboard evaluation process

Marine Eng. Exhaust Emissions – *Big Picture*

- **Worldwide commercial shipping**
  - 95% import/export cargo by sea and 98% diesel engine prop.
  - 5% petroleum fuel consumption (75% residual fuels)
- **Magnitude: marine vessel emission contribution**
  - Worldwide ~(coml. [70%], fish./serv. [18%], & naval [11%])
    16% SO_x, 14% NO_x, ~5% PM, and 2% CO_2
    85% in Northern Hemisphere
    70% within 250 miles of land
- **Shipping fleet growth**
  - World commercial fleet: 86,000 vessels (>100 gross tons)
  - Cargo: 1.5% ↑/ yr. & container: 4 – 10% ↑/ yr. (projected)
  - International trade: 200% in next 10 years (projected)

Worldwide Marine Vessel Traffic

(IMO Study on Greenhouse Gases from Ships)

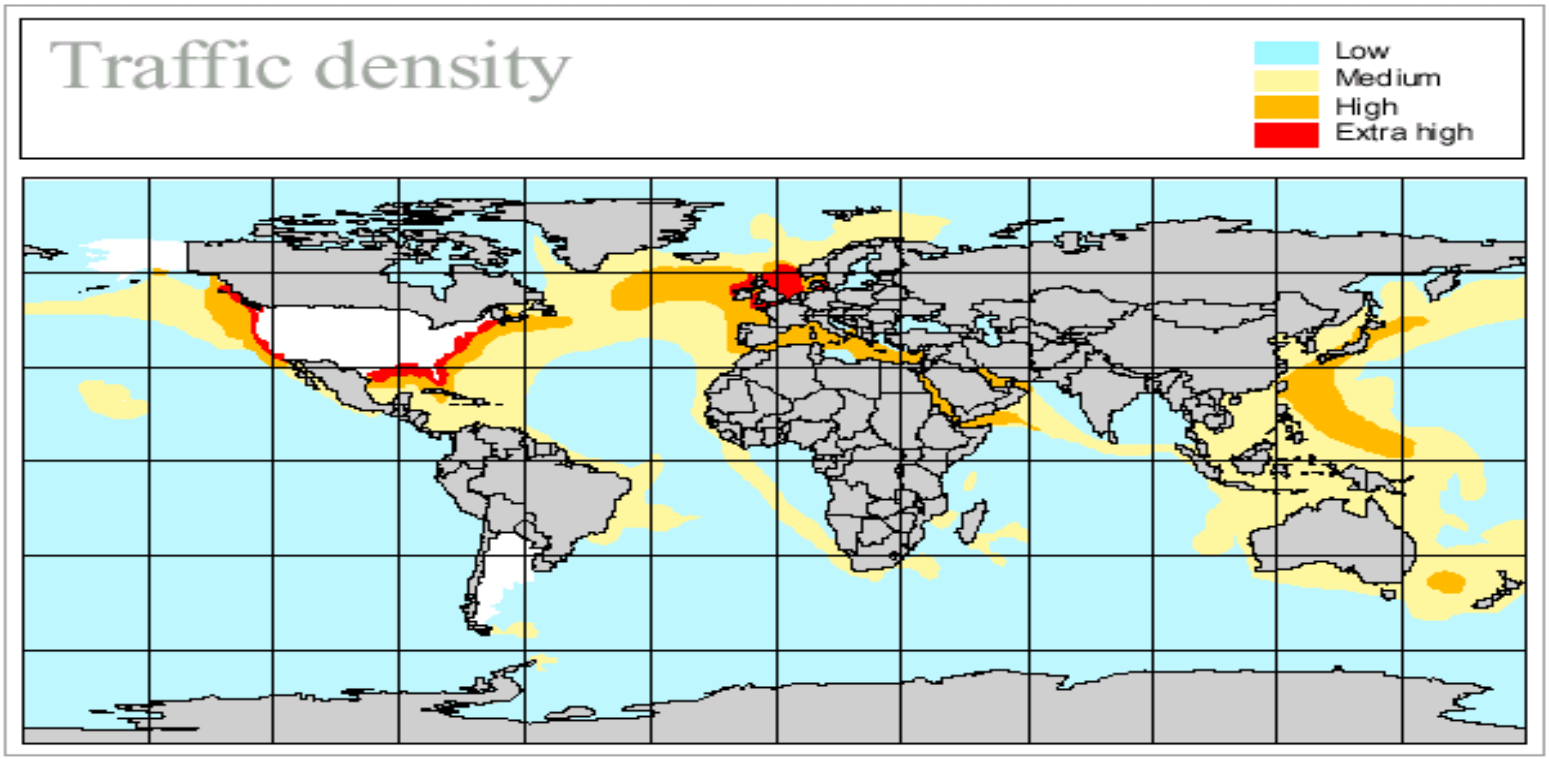


Figure 3-9 Estimated traffic density based on data from 1996.

Navy Marine Eng. Emissions Reduction Program – *Basic Components*

Scope: **Internal combustion, gas turbine, and steam powerplants**

- **Foundational policy and strategy***
- **Introduction of compliant engines***
- **Navy engine emission inventory management**
  - Emission measurement methodology
  - Engine Emissions Calculator (EEC)
- **Technology validation, development, & insertion**
  - Navy Pilot Retrofit Program

Navy Marine Eng. Emissions Reduction Program – *Engine Policy and Strategy*

- **Federal code**
  - Clean Air Act Amendment (CAAA), 42 U.S.C. 7401
- **Navy instruction**
  - OPNAVINST 5090.1B Change 2: Environmental and Natural Resources Program Manual "**19-4.3.1 Compliance with Regulations.** Navy ships shall comply with applicable Federal, State and local regulations governing air pollution emissions."
- **Strategy**
  - Compliant engines for ship acquisition and re-engining
  - Attrition for existing non-compliant engines
  - Gas turbines meet minimum diesel standards
  - Superior Navy modeling and record keeping/maintenance

Navy Marine Eng. Emissions Reduction Program – *Introduction of IMO Compliant Engines*

- **New construction**
  - **LPD-17:** Combatant (C); Caterpillar & Pielstick; 12 ships
  - **LHD-8:** (C); (eng. not yet selected); 1 (+4 possible) ships
  - **MSC T-ADC(X) [T-AKE]:** Combat Support (CS); Fairbanks Morse or Pielstick; 12 ships
  - **MSC LMSR [T-AKR]:** (CS); (Pielstick/Wartsila and Caterpillar); 12 ships
  - **SOCR:** (C); Yanmar; 222 units
  - **JMLS:** (CS); (engine not yet selected); 222 units
  - **LCU(X):** (C); (engine not yet selected); ~ 140 units
- **Repower**
  - **FFG-7:** (C); (engine not yet selected); 60 - 92 units

Navy Pilot Retrofit Program

Intent and Scope

- **Objective:** Identify NO_x/PM retrofit technology options for emissions control
- **Need:** Selective and voluntary application to avoid SIP conformity-induced mission limitations
- **Focus:** High-emission marine diesel eng. **(DDC 71s [2-S NA])**
- **Structure:** Controlled lab perf. testing of select technologies
  Shipboard reliability and durability evaluation
- **Shipboard eval. vessel options:** Navy LCM/LCU & TR/TRB
  MARAD YSD (barge crane)
- **Partners:** CARB, DOE, MARAD, EPA, and SERDP

Navy Pilot Retrofit Program

Technologies Selected for Further Evaluation

- **Target marine diesel engine population**
  - Old, high-polluting engines in high-usage applications

    (Navy: 2,000 DDC 71-Series 2-S NA [1970 – 1990 MY]; also 53-, 92-, and 149-Series & variety of older 4-S engines)*
- **Operating and design conditions**
  - Navy: F-76 (1% S cap) and JP-5 (0.4% S cap)

    Coml: B100-type biodiesel and coml. EPA or CA fuel
  - Low T_{ex} (450 – 800ºF) and low P_{back} (3 – 5 in. HG)
  - Low load-factor operating profiles (10 – 60%)
  - High emissions (9 – 23 NO_x, 0.2 – 1.6 PM, 2 – 4 SO_2, 0.15 – 0.55 HC, and 6 – 49 CO [g/bhp-hr])

Landing Craft, Utility (LCU): Option for Shipboard Evaluation Platform

YSD Barge Crane DDC 12V-71N Port Eng: Option for Shipboard Evaluation Platform

Navy Pilot Retrofit Program

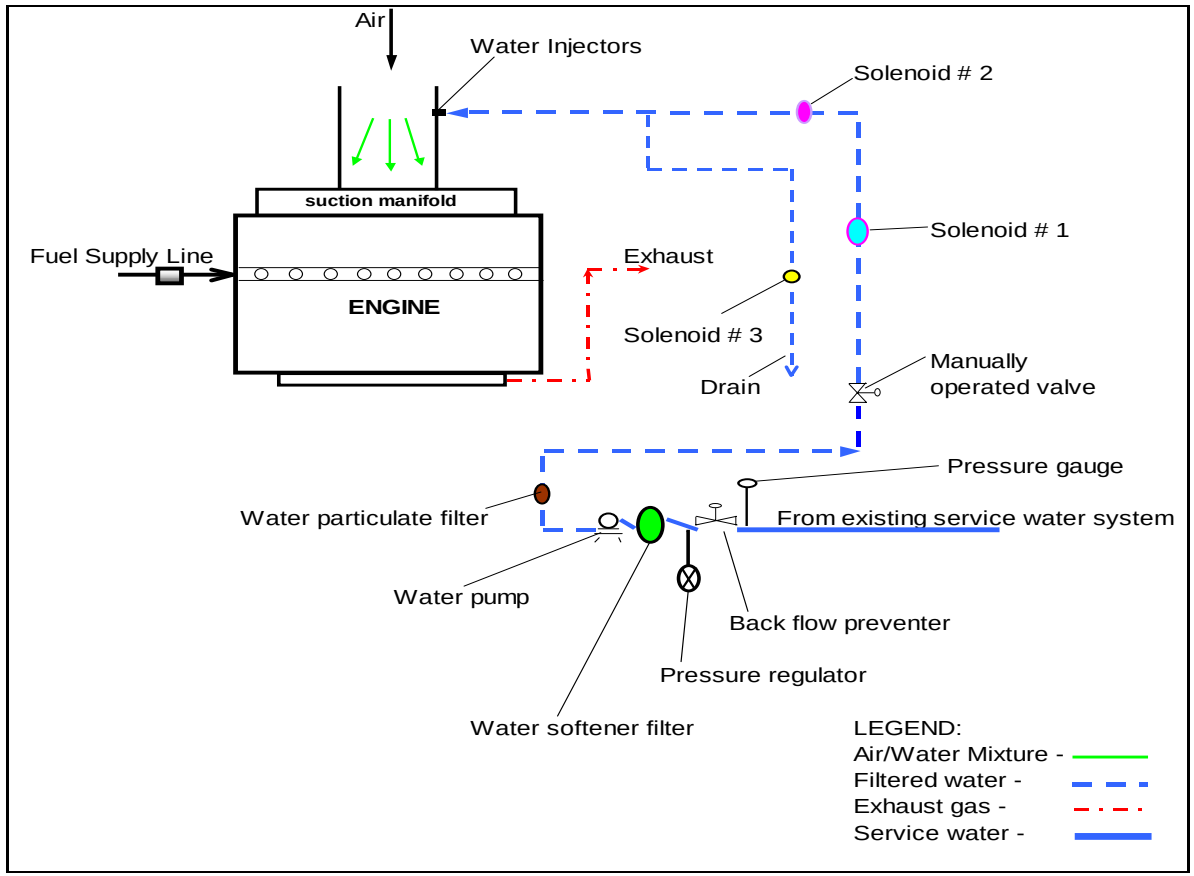
Technologies Selected for Further Evaluation

- **Selection process**
  - Rated submittals:
    Development stage, field use, and cost
    Eng. asmt. of NO_x/PM reduction potential & est. fuel penalty
- **Description of technologies**
  - Identified technol. compatible w/ F-76 / JP-5 or coml. fuels:
    Air Humidification Technology (intake air water injection)
    Catane DFA Diesel Fuel Upgrade (ferrocene fuel additive)
    Clean Cam Technology System (combustion chamber and injector modifications; turbocharger addition)
    ECOTIP Superstack Fuel Injector (small sac volume inj.)
    Subsequently incorporated B100 biodiesel for DOE/MARAD and diesel particulate filter (DPF) for CARB

Navy Pilot Retrofit Program

Air Humidification Technology (AHT)

- **System schematic**



Navy Pilot Retrofit Program

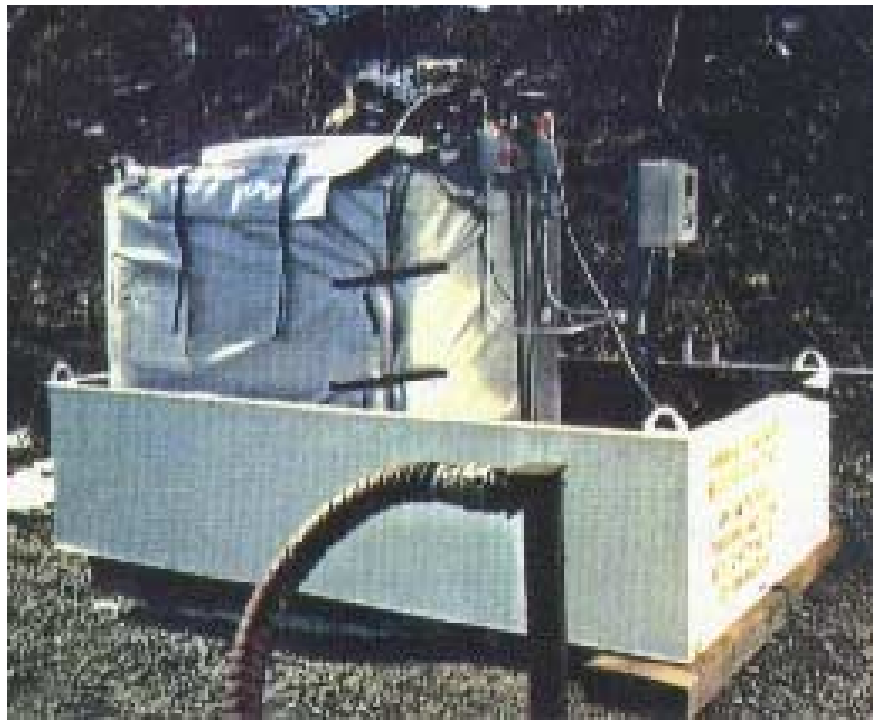
Air Humidification Technology (AHT)

- **System installation**

Navy Pilot Retrofit Program

Catane DFA Diesel Fuel Upgrade

- **Commercial automated dosing system**



Navy Pilot Retrofit Program

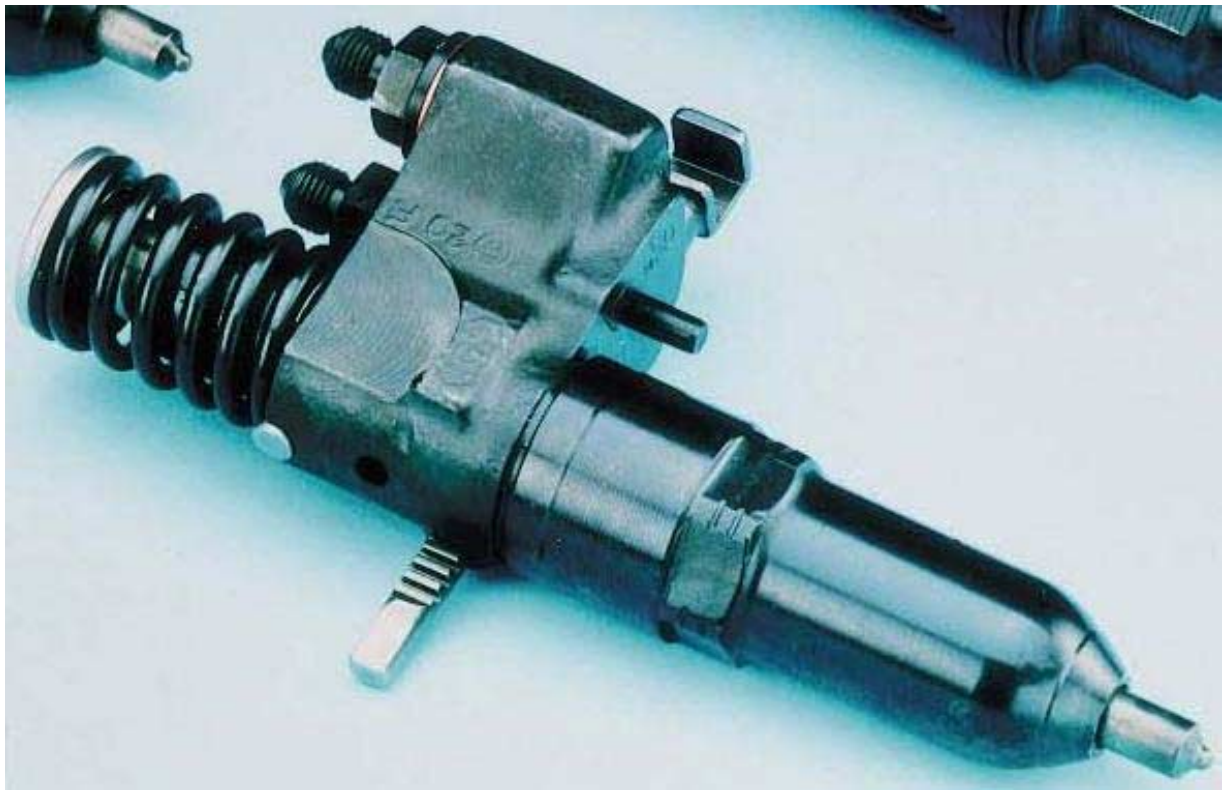
Clean Cam Technology System (CCTS)

- **Replacement engine components**

Navy Pilot Retrofit Program

ECOTIP Superstack Fuel Injector

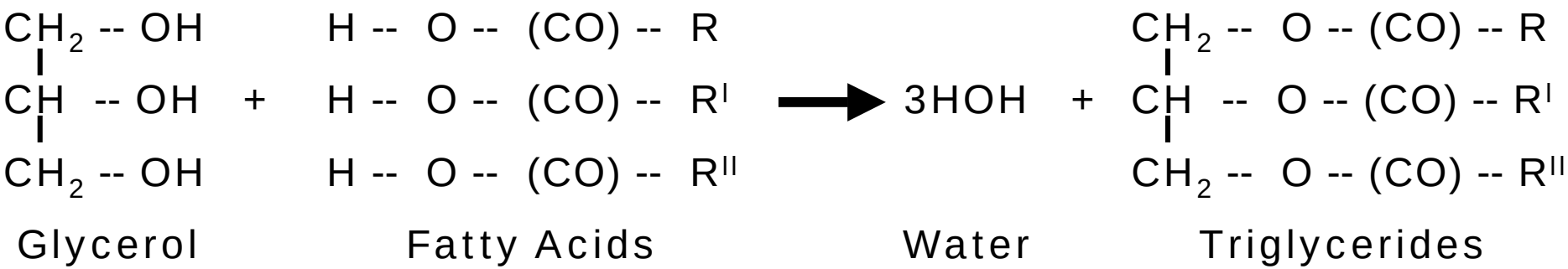
- **Replacement injector**



Navy Pilot Retrofit Program

Neat Biodiesel B100

- **Vegetable oil molecular structure**



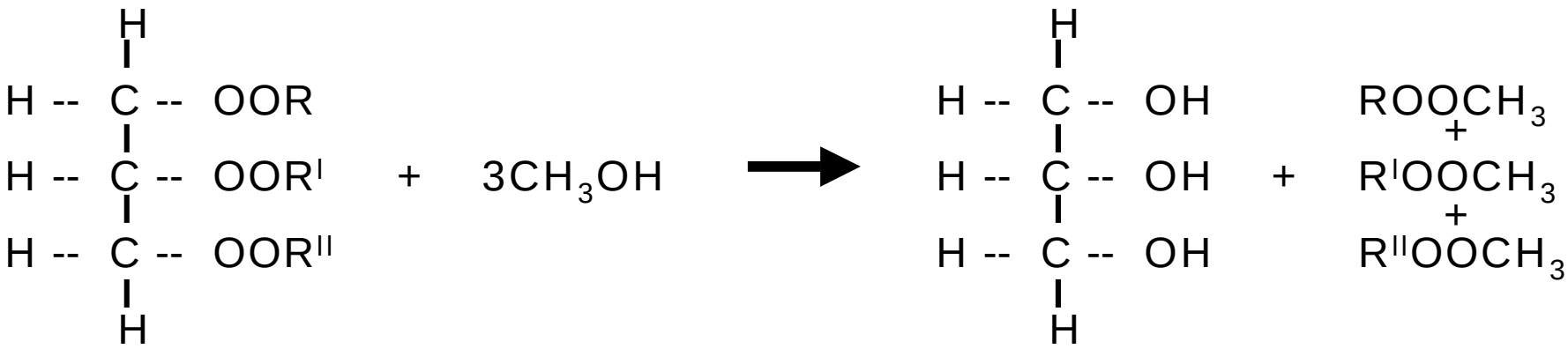
Chemical Structure of Triglyceride

Chemical Structure of Fatty Acids

Navy Pilot Retrofit Program

Neat Biodiesel B100

- **Vegetable modification to form B100 biodiesel**



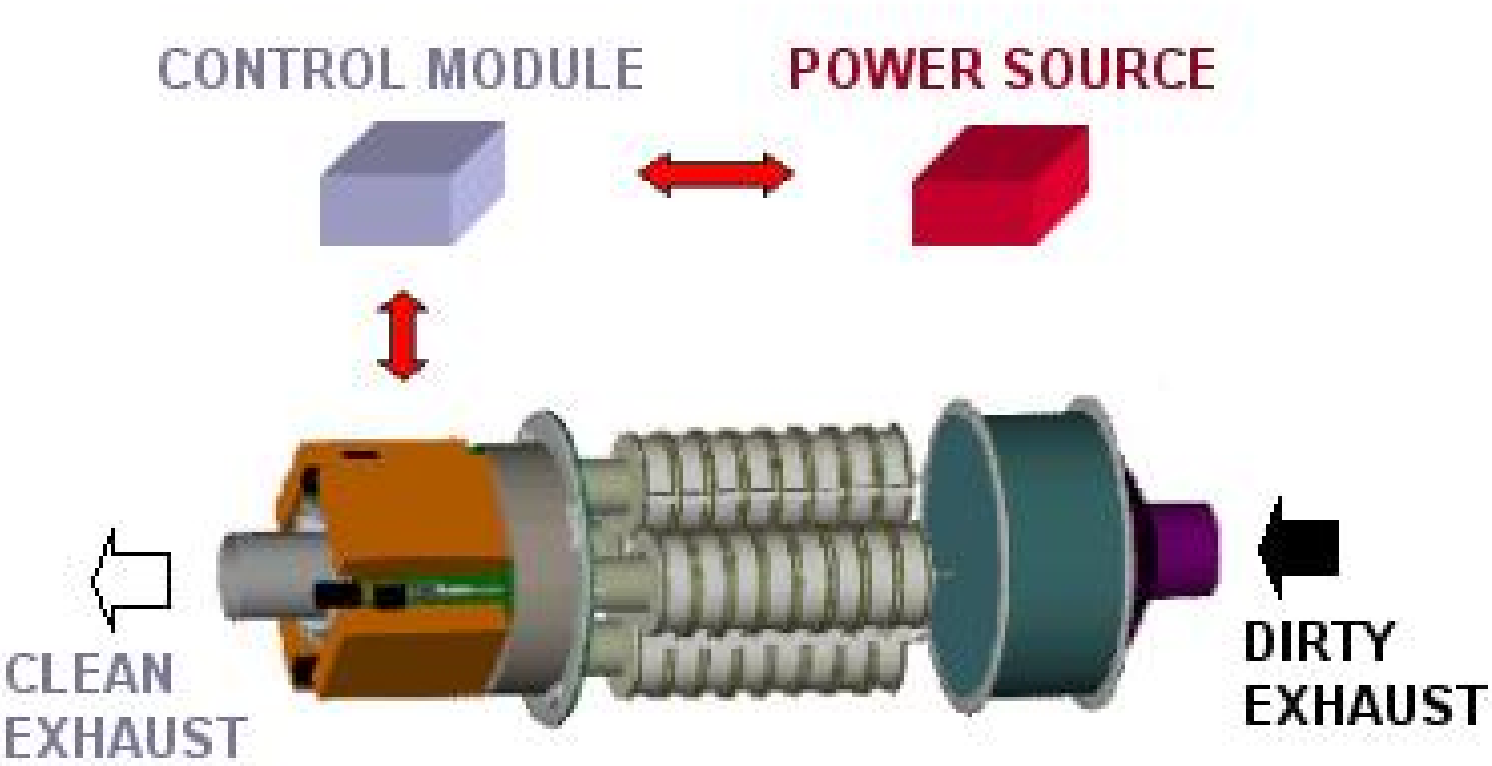
Vegetable Oil + Methyl Alcohol → Catalyst + Glycerol + Methyl Esters

Transesterification of Vegetable Oil

Navy Pilot Retrofit Program

Rypos Active-Regeneration Diesel Particulate Filter

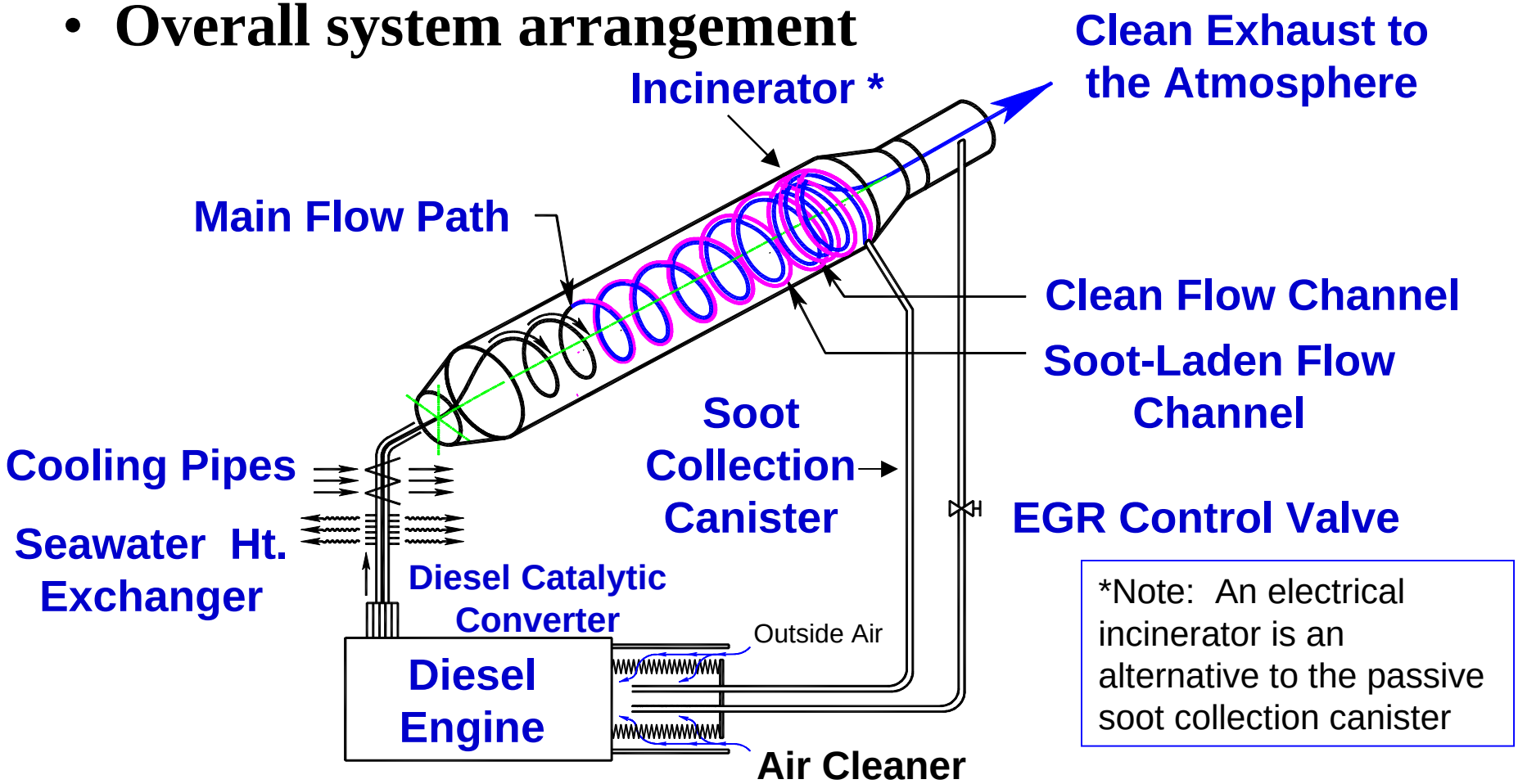
- **AR DPF design**



Navy Pilot Retrofit Program

Converter System

- **Overall system arrangement**

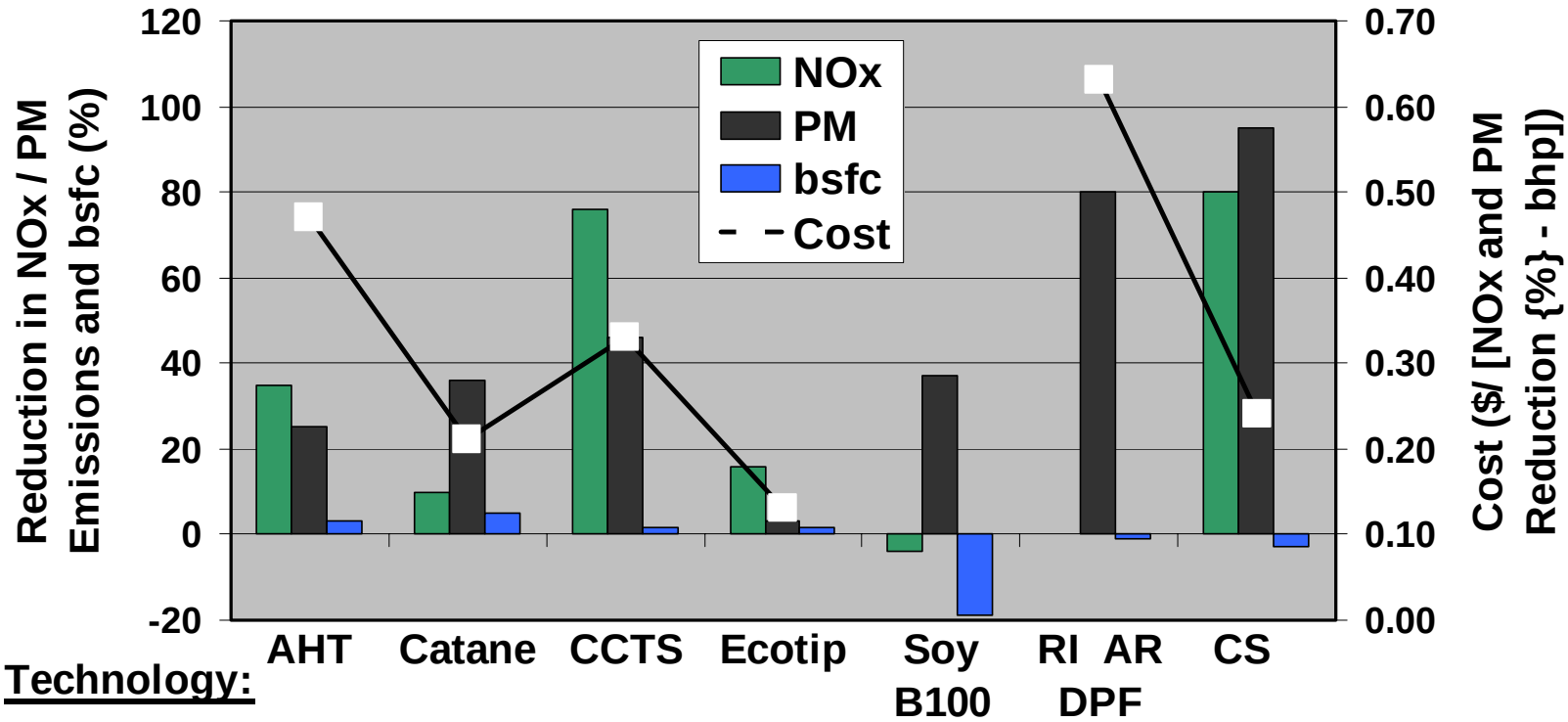


*Note: An electrical incinerator is an alternative to the passive soot collection canister

Navy Pilot Retrofit Program

Technol. Selected for Further Eval. – Cost / Benefit Comp.

Manufacturers' Retrofit Performance and Cost Estimates (DDC 12V-71N marine diesel engine application)



Assumptions: Initial hardware retrofit, fuel additive, or fuel costs represent all costs for 10,000 hr operating period.

Note: B100 cost is $8.6 / %$NO_x$-PM reduction - bhp

Navy Pilot Retrofit Program

Test Plan – Process

- **Controlled lab testing (12V-71N)**
  - Performance and emissions assessment focus
  - Back-to-back baseline engine and modified engine tests
  - Compare single technologies with combinations of technologies to determine most cost-effective modifications
  - Compare performance/emissions impact w/ F-76, JP-5, B100-type biodiesel and coml. EPA or CA fuel
- **Extended shipboard evaluation (12V-71N)**
  - Reliability, durability, and system interface assessment focus
  - 6 – 9 mo. duration
  - Optimal lab technology/combination of technologies

Navy Pilot Retrofit Program

Test Plan – Shipboard Evaluation Process

- **Define shipboard emissions measurement methodology**
- **Select shipboard evaluation vessels/engines**
  - LCM-8 (landing craft mechanized) in San Diego, CA
  - TR (torpedo retriever) or TRB (torpedo recovery boat) in Port Hueneme, CA
  - YSD (barge crane) in San Francisco, CA

Summary

- **Significant marine emissions problem**
- **Navy policy of compliance**
- **Navy emissions reduction will rely primarily on new procurements, but retrofits/alt. fuels necessary response to SIP conformity-induced mission limitation**
- **Pilot program: broadly collaborative / narrowly targeted (application / technologies)**

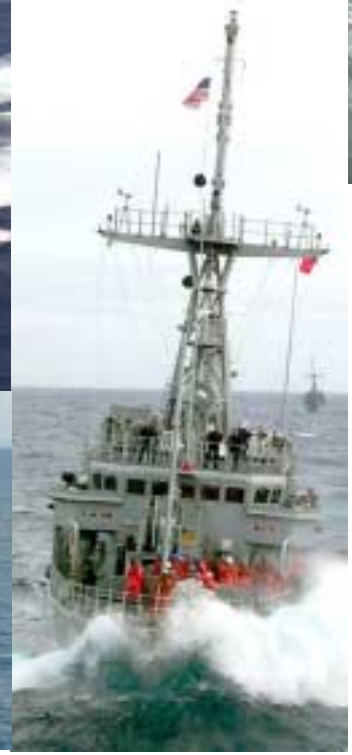
will serve as marine emissions protocol / instrumentation proving ground, for short-term performance and longer-term RMD evaluation

NAVSEA PHILADELPHIA

Ship Systems Engineering Station

CODE 932 DIESEL ENGINE & POWER TRANSMISSION BRANCH

Marine Engine Exhaust Emissions POC



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