

# APL Singapore Slide Valve & Water-In-Fuel Emulsion Demonstration Project

## Technology Manufacturer

MAN B&W Diesel

Sea to Sky Pollution Solutions

## Co-Participants

Port of Long Beach, Port of Los Angeles, University of California-Riverside CE-CERT, Bay Area AQMD, Ventura County APCD, San Luis Obispo County APCD, Santa Barbara County APCD, California Air Resources Board, U.S. EPA Region 9



## Background

The Technology Advancement Program completed participation in a demonstration of emission reduction technologies aboard the container ship *APL Singapore*. Two emission control technologies were demonstrated - the use of slide valves in the vessel's main engines, and water-emulsified bunker fuel using an innovative onboard water in fuel emulsifier.

## Project Objective

To investigate the technical feasibility, engineering requirements, and potential for replication in other ocean going-vessels (OGVs), the San Pedro Bay Ports partnered with the U.S. EPA, CARB, and a number of air districts to demonstrate two retrofit technologies that have the potential to significantly reduce both particulate matter and oxides of nitrogen (NO<sub>x</sub>) emissions. The primary objectives of the demonstration project were to:

- Evaluate the particulate matter (PM) emission reduction effectiveness of retrofitting OGV main engines with an improved injector design known as a slide valve;
- Demonstrate demand-based onboard water in fuel emulsification system and measure the NO<sub>x</sub> reduction effectiveness of varying the water content.

## Technology Description

**Slide Valve Injectors** – Slide valves installed on the APL Singapore's main engine differ from conventional valves in their spray patterns and are designed to reduce dripping of fuel from the injector during the combustion process. Particulate matter is a product of incomplete combustion and unburned fuel. Optimization of the fuel injection system was expected to result in a reduction in fuel consumption and a reduction of PM emissions on the order of 10% to 25%. The slide valve technology was provided by MAN B&W Diesel (MAN).

**Water-in-Fuel Emulsification (WiFE)** – WiFE is the process of introducing water into fuel prior to injection into the combustion cylinder. The fuel-water emulsion technology was provided by Sea to Sky Pollution Solutions. A fuel homogenizer was installed in the APL Singapore’s engine room to produce the emulsification. Fuel and water are carried by separate lines into a mixing chamber called a “homogenizer/emulsifier” which is essentially a large funnel. Inside the funnel is a rotor that spins with a very small clearance next to the funnel’s walls. The spinning rotor draws in the fuel and water, mixes them together and squeezes the mixture out of the funnel with water present in the fuel as tiny droplets. The water droplets, as small as one micron (0.000001 meter in diameter) are fully contained within the fuel.

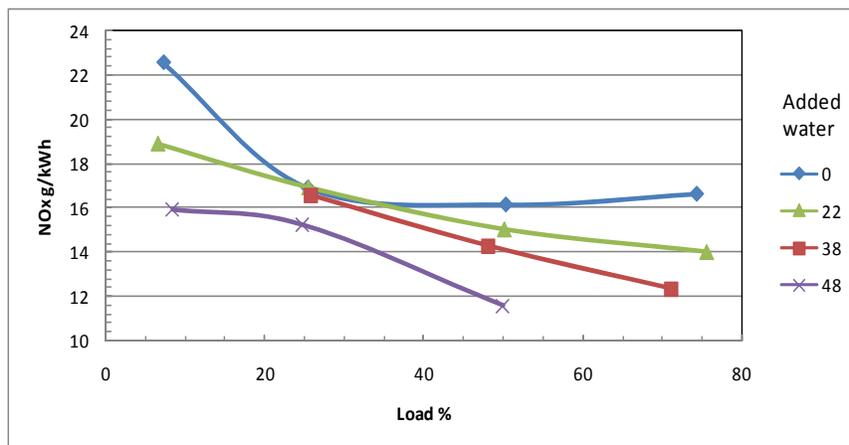
The fuel/water mixture is immediately injected and atomized within the engine’s combustion chamber. The heat inside the combustion chamber causes the water droplets to vaporize into steam – this requires energy from the combustion process and results in lower peak combustion temperatures. The lower combustion temperatures reduce NO<sub>x</sub> formation.

**Results**

The first emissions tests were conducted during a 15-day transpacific voyage from Kaohsiung Taiwan to the San Pedro harbor. Testing was conducted in parallel by University of California-Riverside and MAN B&W. A second test protocol was performed in spring 2008, also conducted by the University of California-Riverside in cooperation with engine manufacturer MAN B&W Diesel.

Project test conditions resulted in an evaluation that indicated the benefits of slide valves appear to be limited. Emissions testing data were inconclusive and a clear determination of the technology benefits could not be made. Due to the importance of reducing emissions from OGVs, additional study was conducted in 2012 to gain more data and experience with slide valves as a potential emission reduction strategy.

Testing of the WiFE system aboard the APL Singapore yielded the results shown below in the figure below. As shown, water concentrations as high as 48% were successfully demonstrated, yielding NO<sub>x</sub> reductions on the order of 30%<sup>1</sup>.



<sup>1</sup> Measurement uncertainty ranges from 3% to 15% for these results.

### **Project Costs**

Seven funding partners contributed approximately \$1.3 million toward this demonstration and evaluation project. The San Pedro Bay Ports, the Bay Area, Ventura County, San Luis Obispo County, and Santa Barbara County Air Pollution Control Districts contributed funds towards the emissions testing element of the project. The San Pedro Bay Ports contributed \$45,000 in TAP funding toward emissions testing.

### **Related Work**

This project demonstrated the potential for NO<sub>x</sub> reductions that can be achieved through OGV retrofit using commercially available emulsification technology. The Ports conducted a follow-up study in 2012 to evaluate the potential for OGV engine emission reductions from the use of slide valves. For more information, please see the OGV Slide Valve Low-Load Emissions Evaluation Project.

Updated: April, 2014

