

Ammonia Combustion Technical Working Group Meeting #6  
March 5, 2024

MAN Energy presentation; Ernst Wilche

- MAN B&W ammonia engine development
- Q&A
  - Clint Bedick (NETL) – All liquid injected?
    - Yes, for ammonia.
  - Rob Steele – Has ammonia been a fuel of the past for marine?
    - Not to his knowledge
  - Peter Herena – 15% pilot fuel?
    - Yes, that was pilot fuel. Fuel oil to create the initial flame and ammonia injected into flame. Currently running 10-15%. Target is 5%. Pilot is running at all times – never 100% ammonia.
  - Peter Herena – When is the catch system intended for use?
    - When switching from ammonia to fuel oil, there will be residual ammonia in the system. Purge that with nitrogen and use the ammonia catch system to prevent ammonia release to atmosphere. This all happens while running.
  - Chat – Were low NOx emissions before or after aftertreatment?
    - Before. And wish to have zero NH3 slip, but after treatment will treat it if there is any.
  - Chat – Elaborate on tuning to reduce N2O emissions?
    - Unsure if stoichiometric or timing tuning that is able to do this.
  - Chat – Comment on corrosion and ammonia compatibility
    - Many materials already used were ok. There is a slide in the full presentation deck that addresses this.
  - Chat – What is the scale of onsite ammonia storage?
    - They don't really store much. Tank on site is maybe 5 cubic meters. They bunker ammonia everyday because they do not want to store. Ammonia already being shipped around the world, so should not be an issue to have it onboard for burning.
  - Emissions measurements
    - They will measure emissions from same spot in 3 hydrocarbon cylinders and 1 ammonia cylinder for the 4-cylinder engine.

TU Munchen presentation; Valentin Scharl

- Ammonia as a fuel for high-pressure direct injection in marine engines
  - Spray combustion via diesel process; use pilot fuel with high cetane number; non-premixed ammonia as main fuel
  - Large marine engines facilitate ammonia spray combustion
    - Favorable to auto-ignition; reduced N2O & NH3 emissions; exhaust gas after treatment
- Q&A
  - Peter Herena – Explain difference in performance b/t 2-stroke and 4-stroke.
    - 2-stroke mainly for large marine applications. 4-stroke for smaller marine or power generation.

- Peter Herena – CAPSAM
  - Includes all of the intermediate tanks between ammonia storage and test engine.
- Clint Bedick – Ammonia storage pressure
  - About 20 bar.
- Peter Herena – Describe the PPE needed for normal operation?
  - Usually just an ammonia gas mask and not much else needed. You can recognize if it exceeds 5 ppm.
- Chat – Co-firing can create HCN
  - Yes, they checked this. Most hydrocarbons consumed in pilot before interacting with ammonia. But could be more problematic with premixing of hydrocarbons and ammonia.
- Wesley Boyette – Only single-hole injectors studied?
  - Nothing else studied in the fundamental test rig.
- Measurements of emissions. What about effects of sampling on NO<sub>x</sub> measurements – freezing reactions along sampling pathway – has anyone looked at this?
  - Concerned with measurements on H<sub>2</sub> in exhaust. Usual FTIR measurements do not measure that well.

MAN Energy presentation; Brian Fladger

- Moving big things to zero. Maintaining Reliability Throughout the Energy Transition.
- Q&A
  - Clint Bedick – On comparison between battery and chemical storage, did you look at battery capacity?
    - Yes, they did evaluate different battery sizes.
  - Rob Steele – Are you suggesting ammonia storage on site as backup?
    - They made the assumption of 2 weeks of ammonia on site as backup fuel. Also assumed \$850/ton landed price.
  - Peter Herena – What quantity of ammonia for 2 weeks?
    - 50 MW @ 100% capacity factor for entire 2 weeks. 336 running hours. Does not know the quantity of ammonia needed for this.
  - Clint Bedick – What are your thoughts on H<sub>2</sub> vs NH<sub>3</sub>?
    - Cost of transport of H<sub>2</sub> relates to proximity to hydrogen hub. Ammonia may make more sense in some cases, hydrogen in others. They also included cost of cracking ammonia into hydrogen. And cost of hydrogen to produce ammonia.
  - Chat – Economics of cracking ammonia back to hydrogen on site.
    - That adds cost. Depends on utilization technology. Would not be worth it to crack the ammonia unless there was no good way to combust ammonia directly or some revenue stream from N<sub>2</sub> generated.