Introduction to ISB: RRT5

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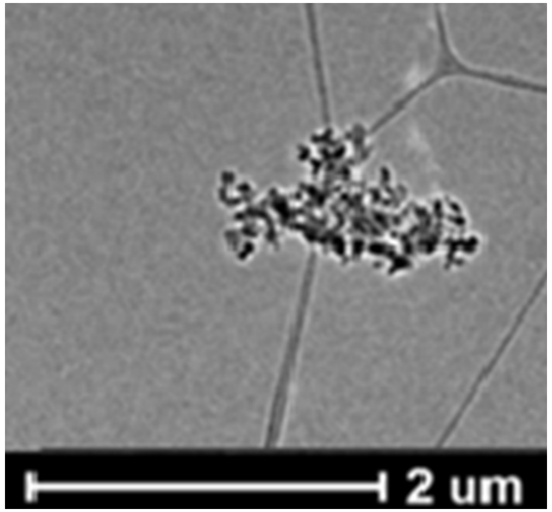
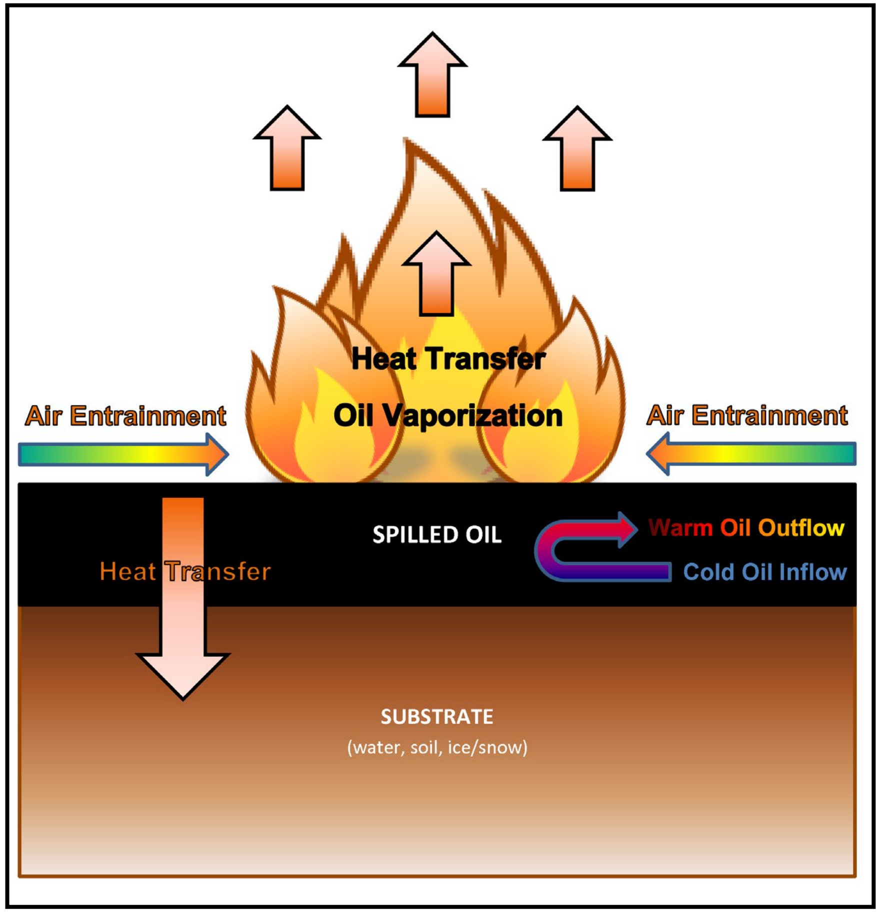
ISB Fundamentals

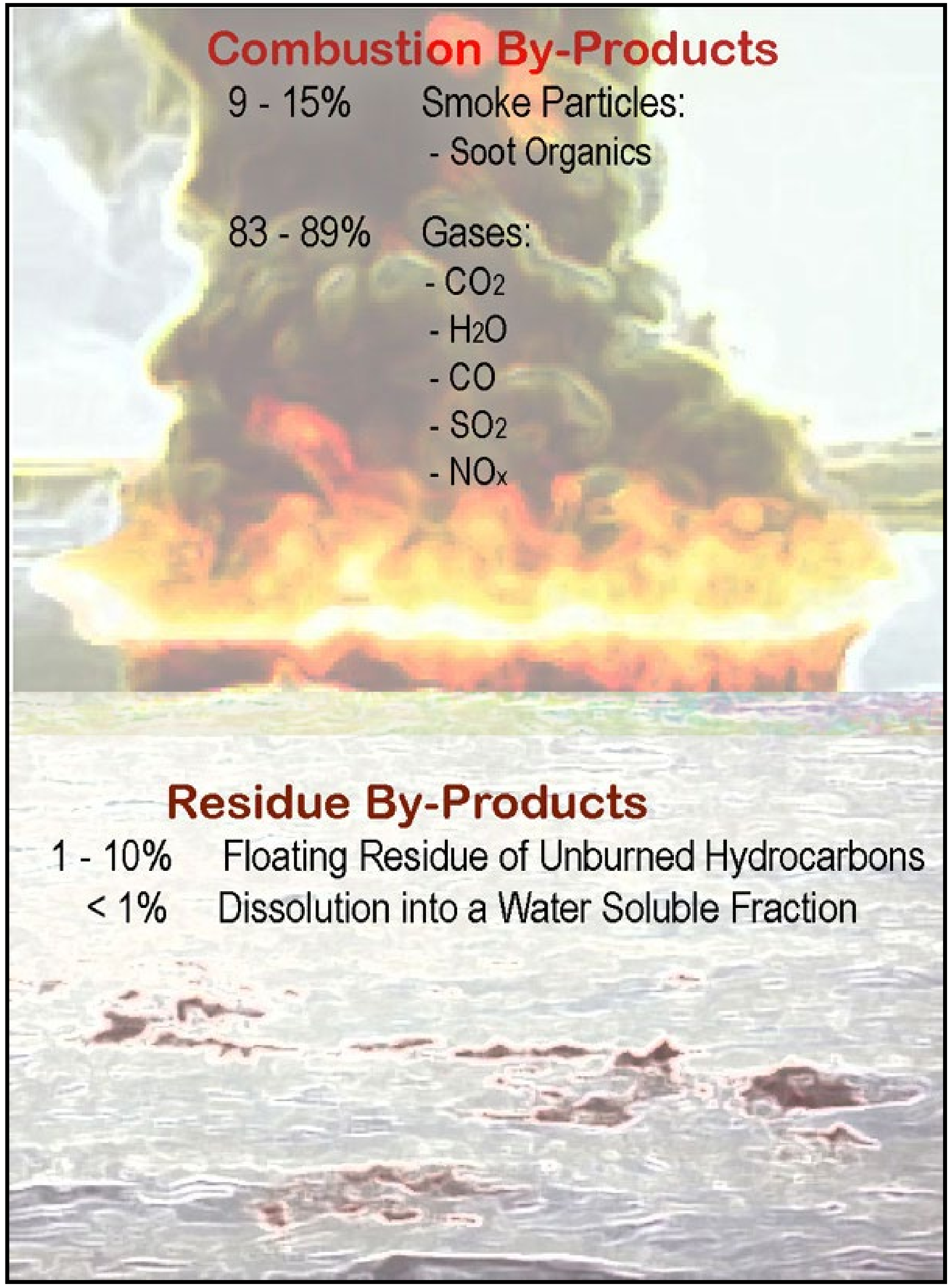
- Requirements: Fuel, oxygen, and ignition source
- Fuel is provided by <u>vaporization</u> of the liquid oil
- Vaporization ends when the oil is 0.5-1 mm thick due to heat loss, so efficiency is a function of the initial slick thickness
- Soot formation (incomplete combustion) is the result of:
  - When vaporization is higher than combustion
  - Partial combustion of fuels such as diesel (that tend to atomize rather than vaporize)
  - Aggregation of molecular species into larger compounds



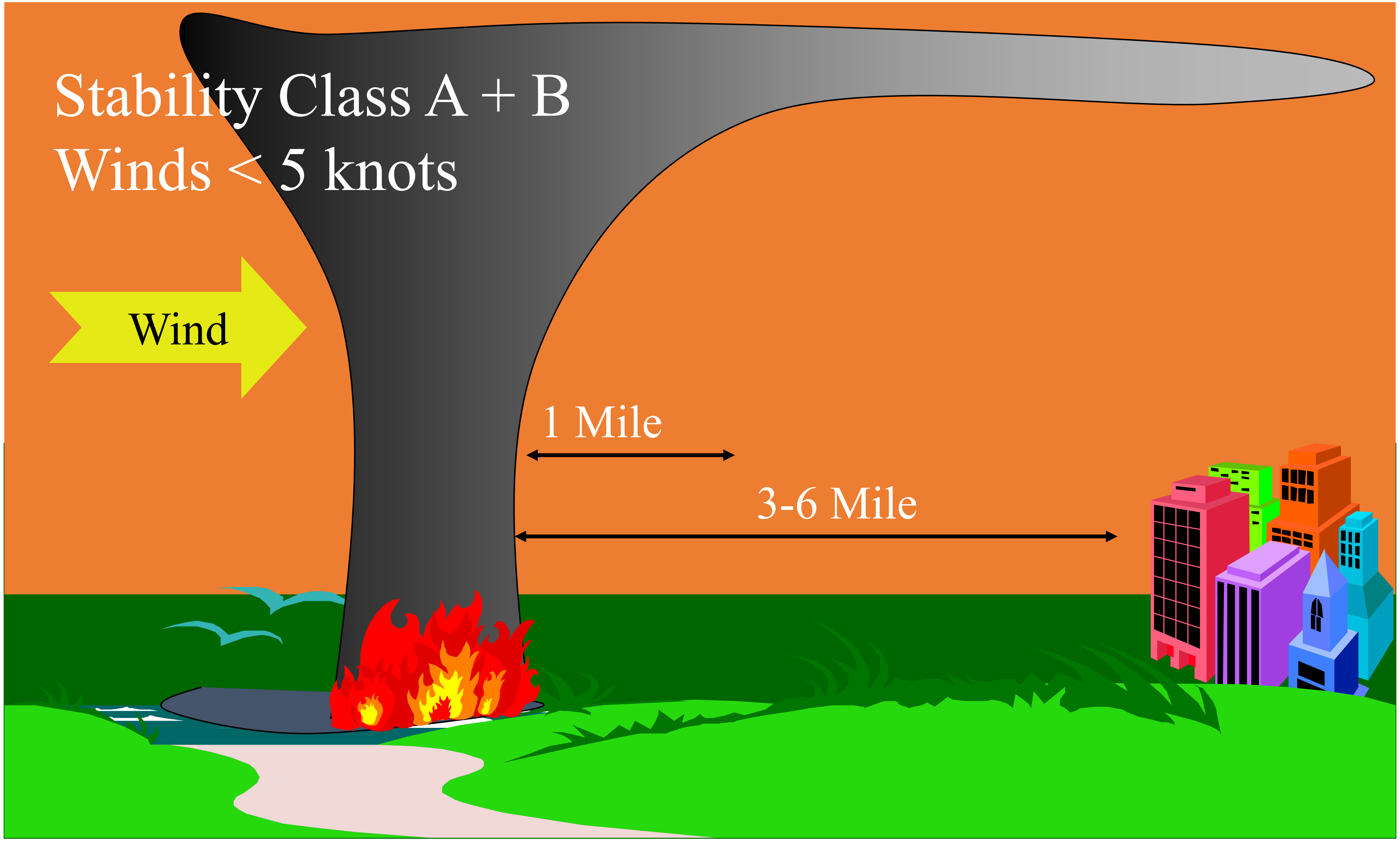
Faksness et al. 2021

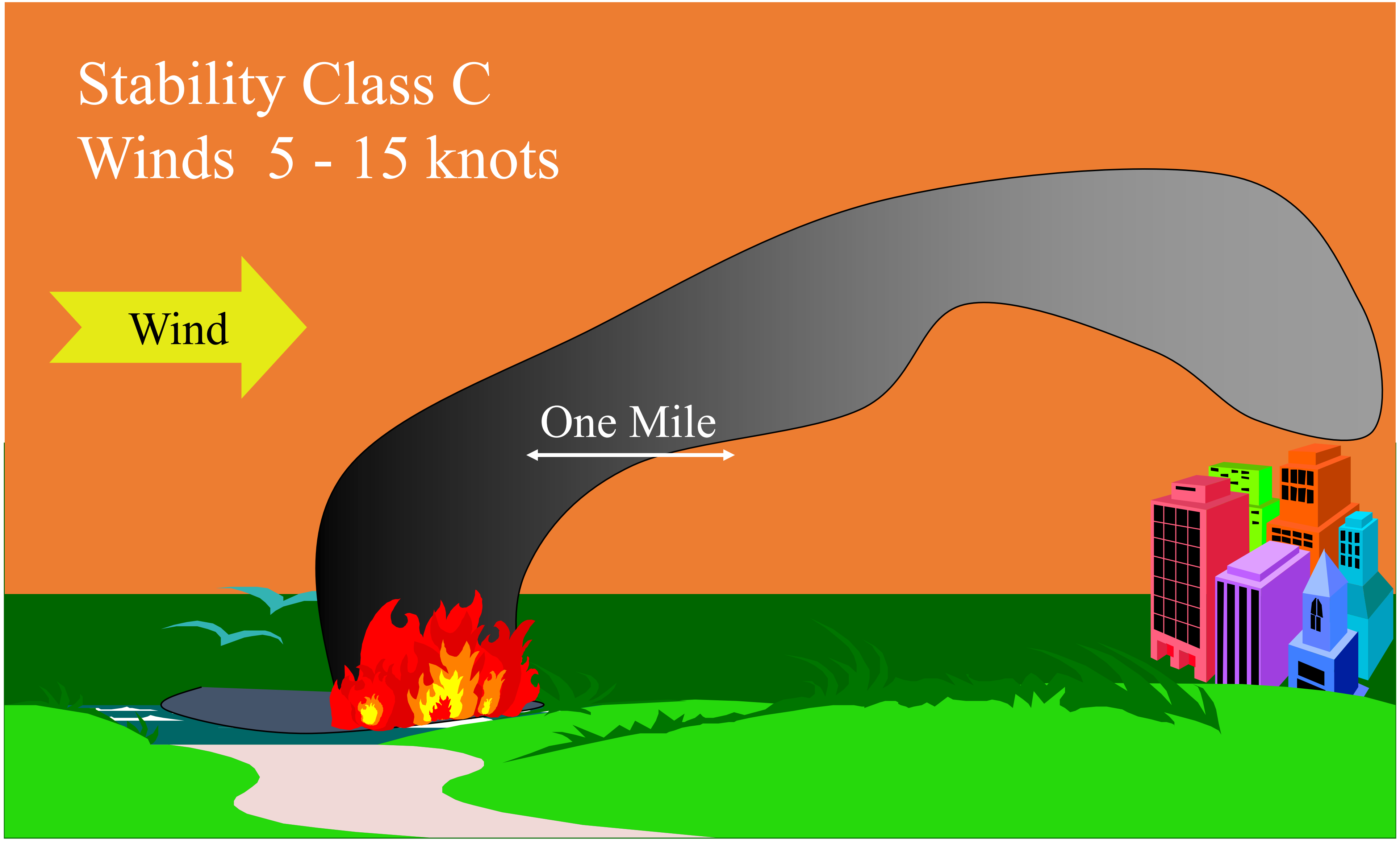


The liquid oil is heated to form vapors; the vapor burn



Modified from Ferek et al. 1997


Stability Class A + B
Winds < 5 knots
Wind
1 Mile
3-6 Mile


Stability Class C
Winds 5 - 15 knots
Wind
One Mile

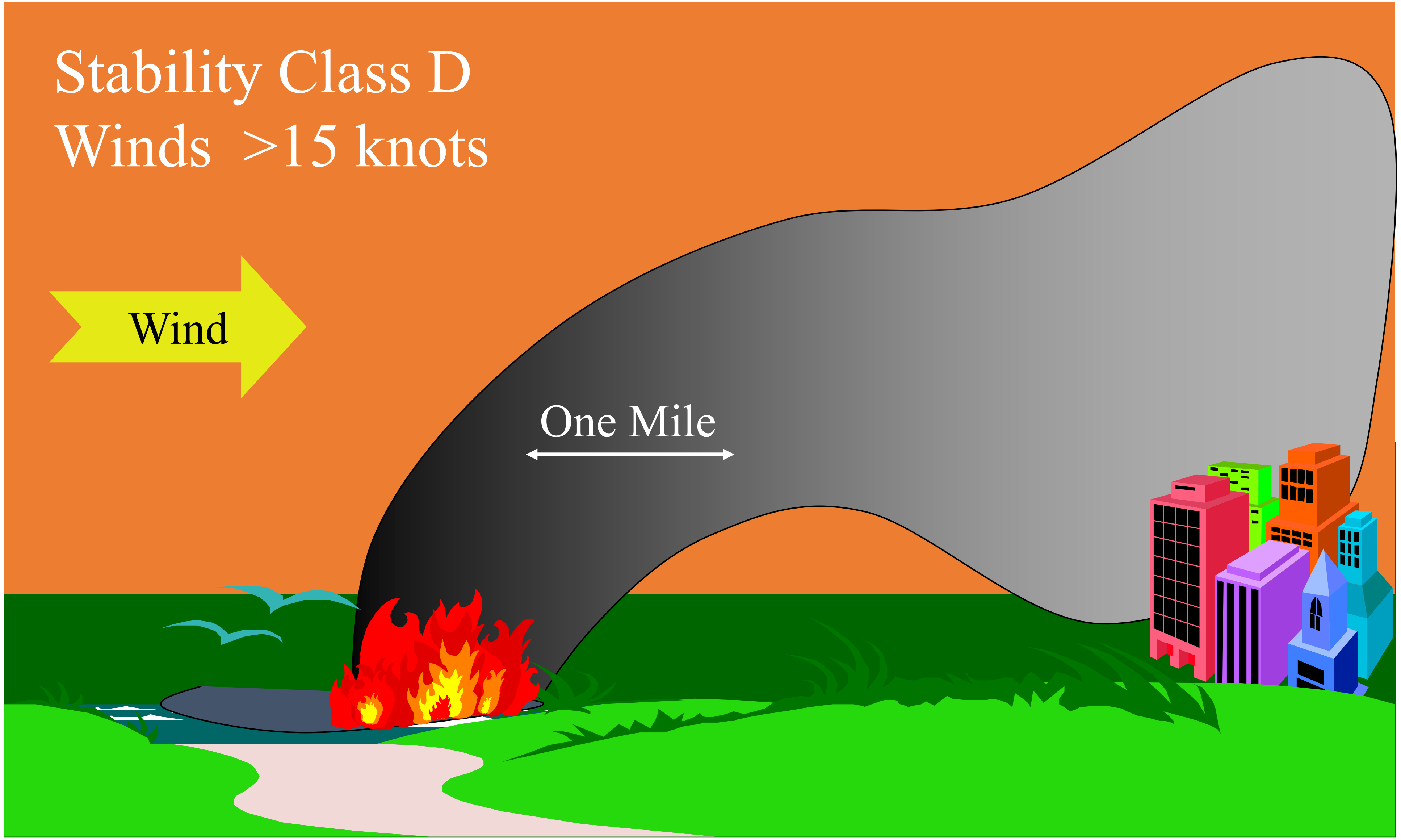
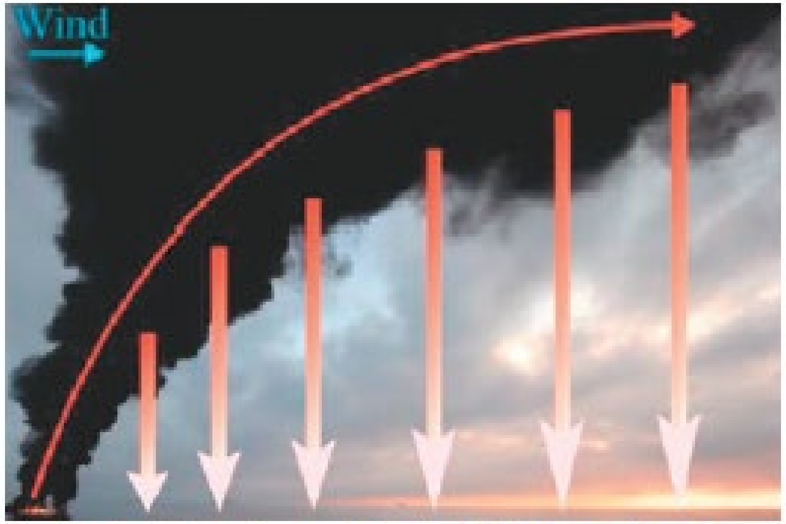
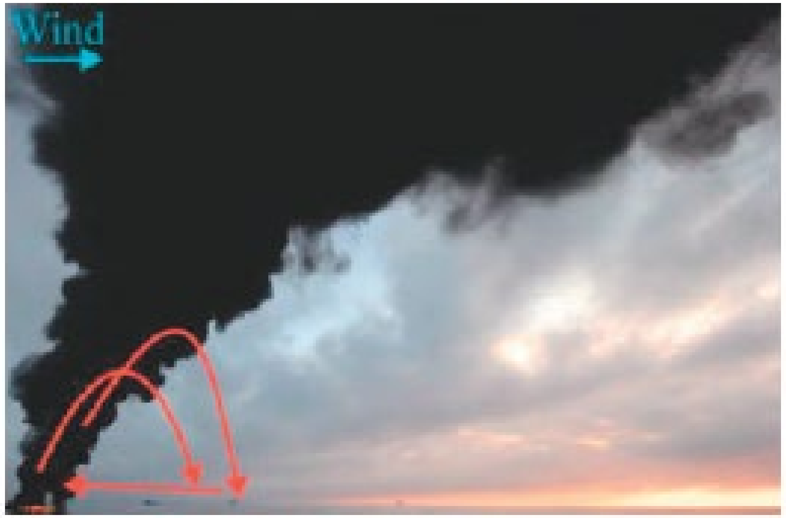

Stability Class D
Winds >15 knots
Wind
One Mile

Figure 7 *Behaviour of different combustion emissions in a burn plume*



a) *Particulates along with adsorbed organics, e.g. PAHs, rise and are then precipitated downwind.*

b) *Water vapour and light gases rise and are widely transported and diffused.*



c) *Carbon dioxide and other heavy gases rise and then slowly sink, and may cycle through the fire.*

Merv Fingas

d) *Organic gases, such as VOCs and carbonyls are widely diffused and diluted.*

ISB Limits – Oil Properties/Wind

- Emulsified oils
  - 12.5% water content - no effect; readily burns
  - 12.5-25% water - reduced effectiveness
  - >25% - generally not effective for ISB, because large amount of energy is needed to heat the water in the emulsion (but research is working to increase burning of highly emulsified oils)
- Oil thickness – should be at least 2-3 mm; thicker is better
- Wind < 12 mph

ISB Requirements – On Land/Creeks

- 1-2 cm water layer or saturated soils, but no peat soils; the peat will burn (Enbridge Pipeline, Cohasset, Minnesota, 2002)
- Free oil present
- Fire breaks
  - Disking to remove flammable vegetation
  - Digging trench/creating dikes
  - Wet lay down vegetation
  - Controlled burn of flammable vegetation at edge of burn area
  - Snow and ice can provide natural containment (Ash Coulee Creek, ND spill of Bakken crude oil, with 1,374 ISBs from 15 Dec 2016 – 23 March 2016, consuming 3,500-4,900 bbl)

ISB Requirements – Snow and Ice

- Snow with 70% oil content will successfully sustain a burn (Buist, 2007)
- Oiled snow can be plowed into piles and burned right on the ground or on the ice
- Or oiled snow can be hauled to a burn pit for burning
- In ice-covered rivers, can cut troughs downstream of the release and burn the accumulated oil
- If the oil is encapsulated in ice, the ice can be removed and treated by melting and recovery or burning of the oil

Ash Coulee Case History
(Steve Merritt, EPA)

In Situ Burning: A Decision Maker's Guide

API TECHNICAL REPORT 1256
OCTOBER 2016

AMERICAN PETROLEUM INSTITUTE

In Situ Burning: A Dec

API TECHNICAL REPORT 1256
OCTOBER 2016

AMERICAN PETROLEUM INSTITUTE

Field Operations Guide for In-Situ Burning of Inland Oil Spills

API TECHNICAL REPORT 1251
FIRST EDITION, JULY 2015

AMERICAN PETROLEUM INSTITUTE

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ISB Residues: Chemical Characterization and Toxicity

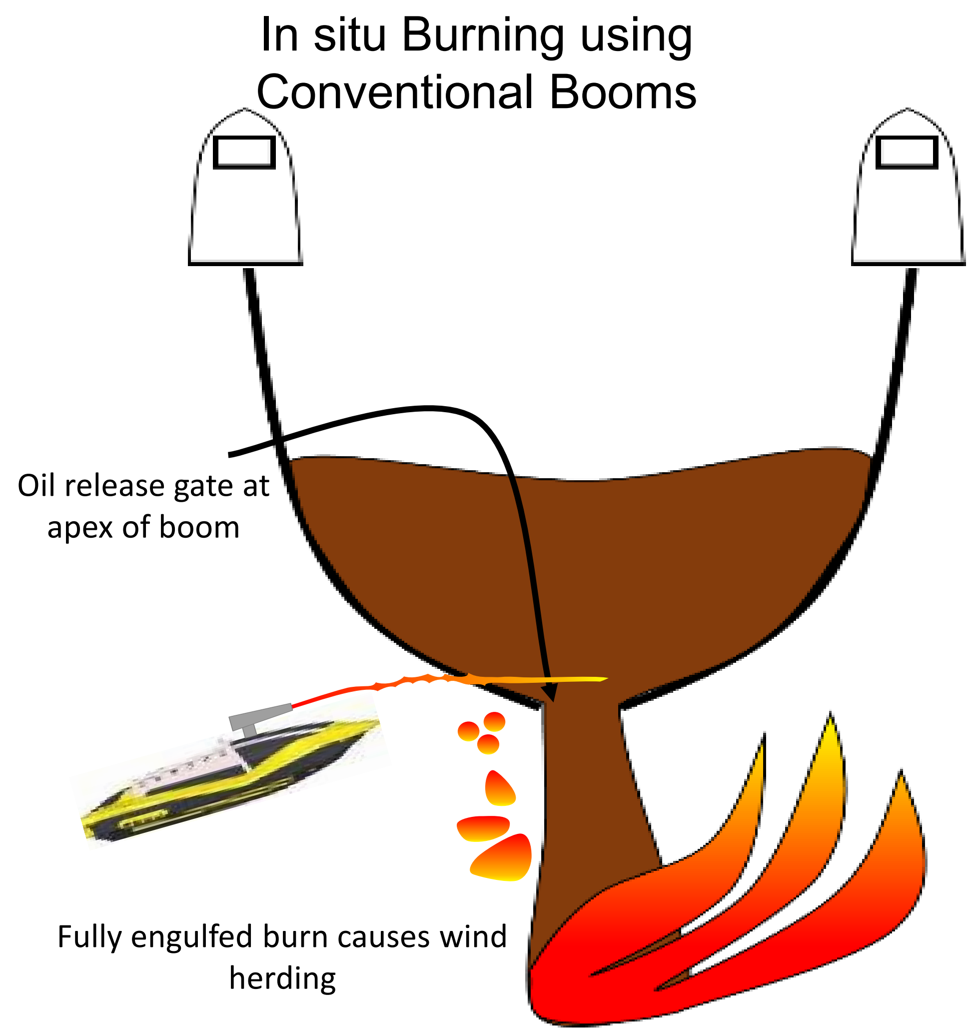
Photo: A. Allen

- Residue properties depends on efficacy of the burn and oil type:
  - Are semi-solid to solid
  - Highly viscous
  - Can sink if result of thick oil slick and heavier oil
  - Can float initially but sink after cooling
- Weathering time did not affect residue composition; PAH reduction overall; some increase in 4-ringed parent PAHs (Fritt-Rasmussen et al. 2013)
- WAF from residues contained PAHs <90% of original oils (Faksness et al. 2022)
- No mortality and minor sublethal effects to egg-bearing shrimp and larvae exposed 2 weeks to residue on gravel (Keitel-Groner et al. 2021)

Recent Innovations for ISB

- Remotely operated surface vehicle (ROSV) to deploy herders (to thicken the slick) and gelled gasoline (for ignition)
- Gated Burning Tongue technique that uses conventional boom (could be used in fast waters, with temporary oil collection)
- Low-Emission Crude Oil Combustor "BSEE Burner” (for emulsified oil)
- Soot reduction and burn efficiency (Flame Refluxer technique, iron oxide nanoparticles, fire whirls, steam injection)
- Proposed Multi-Partner Research Initiative Offshore Burn Experiment (MOBE) to test many of these innovations

Burning Tongue



Issue:
- Fire boom is a logistical challenge to deploy offshore because of its weight and complexity
- Heat from multiple burns destroys boom (5 – 8 burns possible)

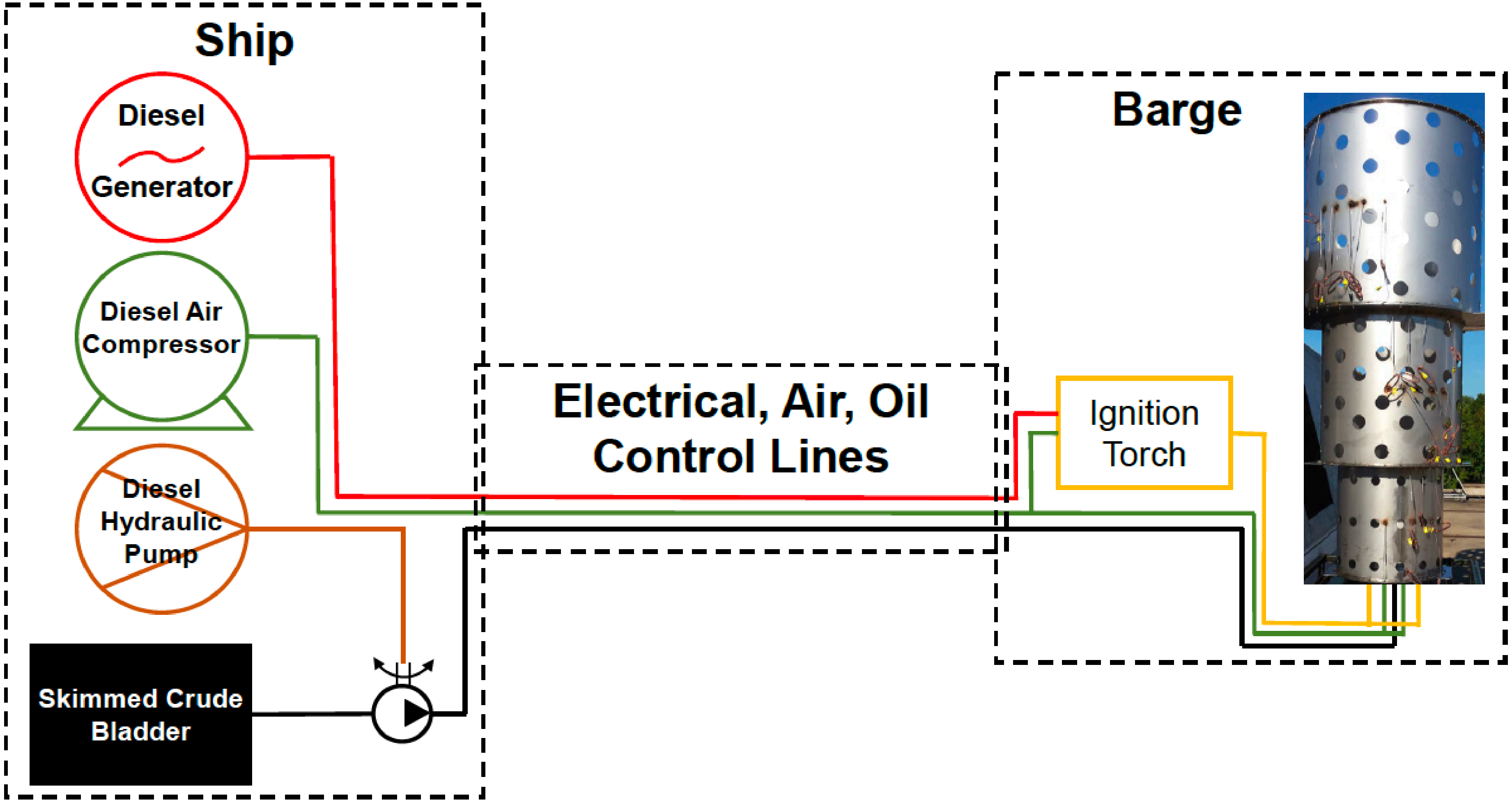
Concept:
- Conduct ISB using conventional ocean boom – no fire boom
- Corral & thicken oil slicks, open gate at the apex of the boom to produce finger of thick burnable oil
- Immediately ignite finger once the oil leaves the boom.
- Within a few 10s of seconds, the finger will fully engulf in flame: convective winds from the burn will cause additional oil thickening.
- Field tests in the 80s demonstrated concept as did burns during DWH
- Burning a thin, long finger more efficient than standard pool fire

Status
- Tested the concept at Ohmsett in June 2019

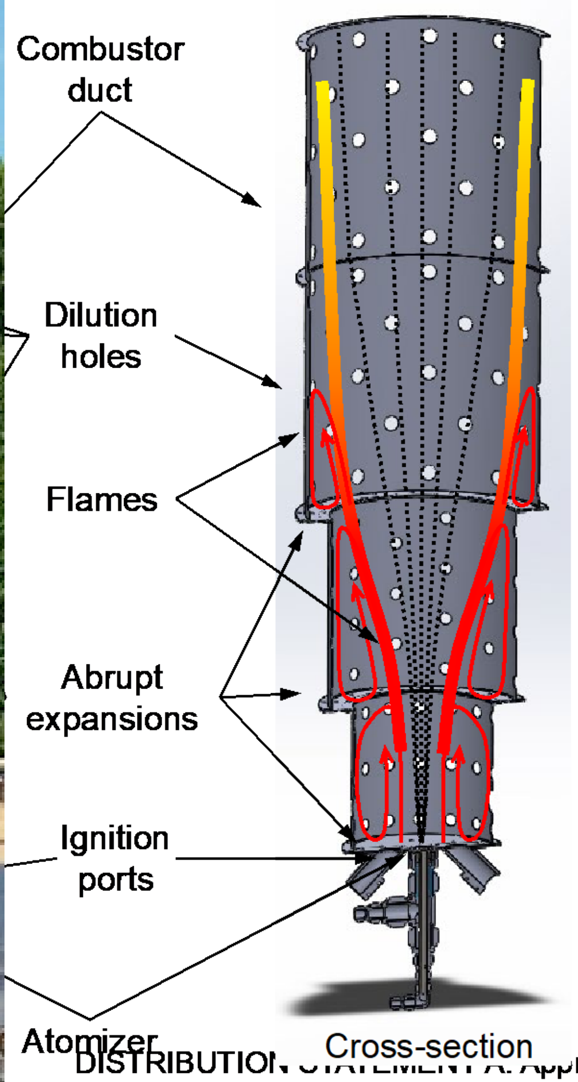
Next steps
- Build / test a full-scale system
- Test during MPRI field demonstration

Tim Nedwed & Lin Zhao, ExxonMobil Upstream Research Company

Supporting infrastructure on vessel



Combustor Design – Open Source IP

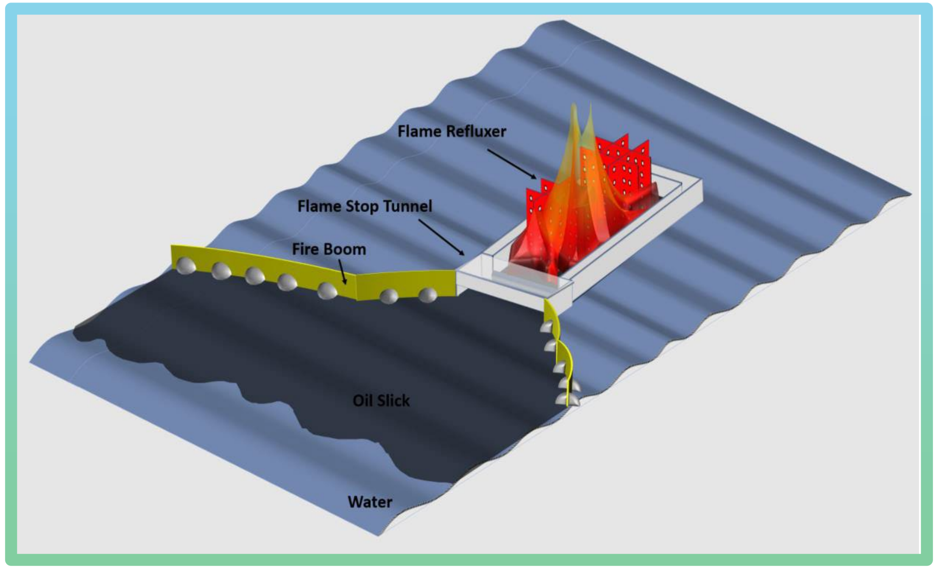


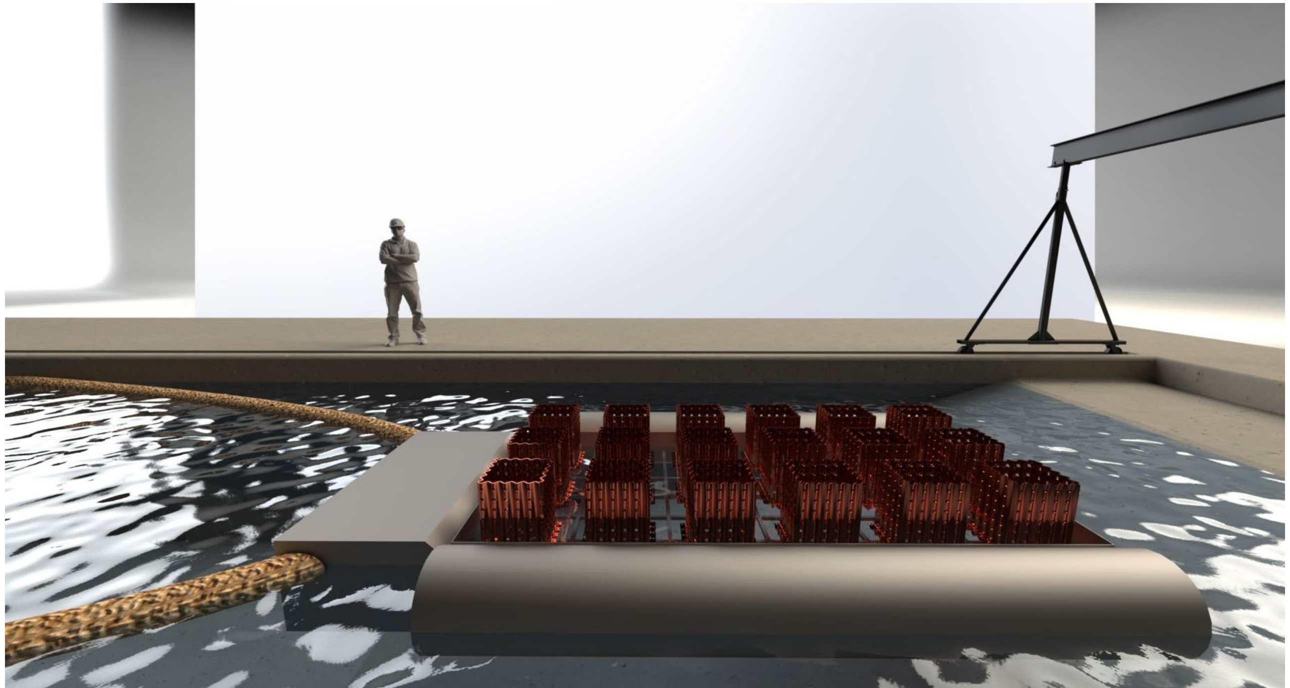
- Low-pressure atomizer discharges crude oil spray into combustor duct.
- Multiple abrupt expansions recirculate hot combustion gases and cool reactants to anchor plume flames.
- The duct wall reflects heat back to the burning plume to evaporate oil, catches droplets
- Dilution holes allow air to mix with the burning plume.
- **Operates with just two sections**

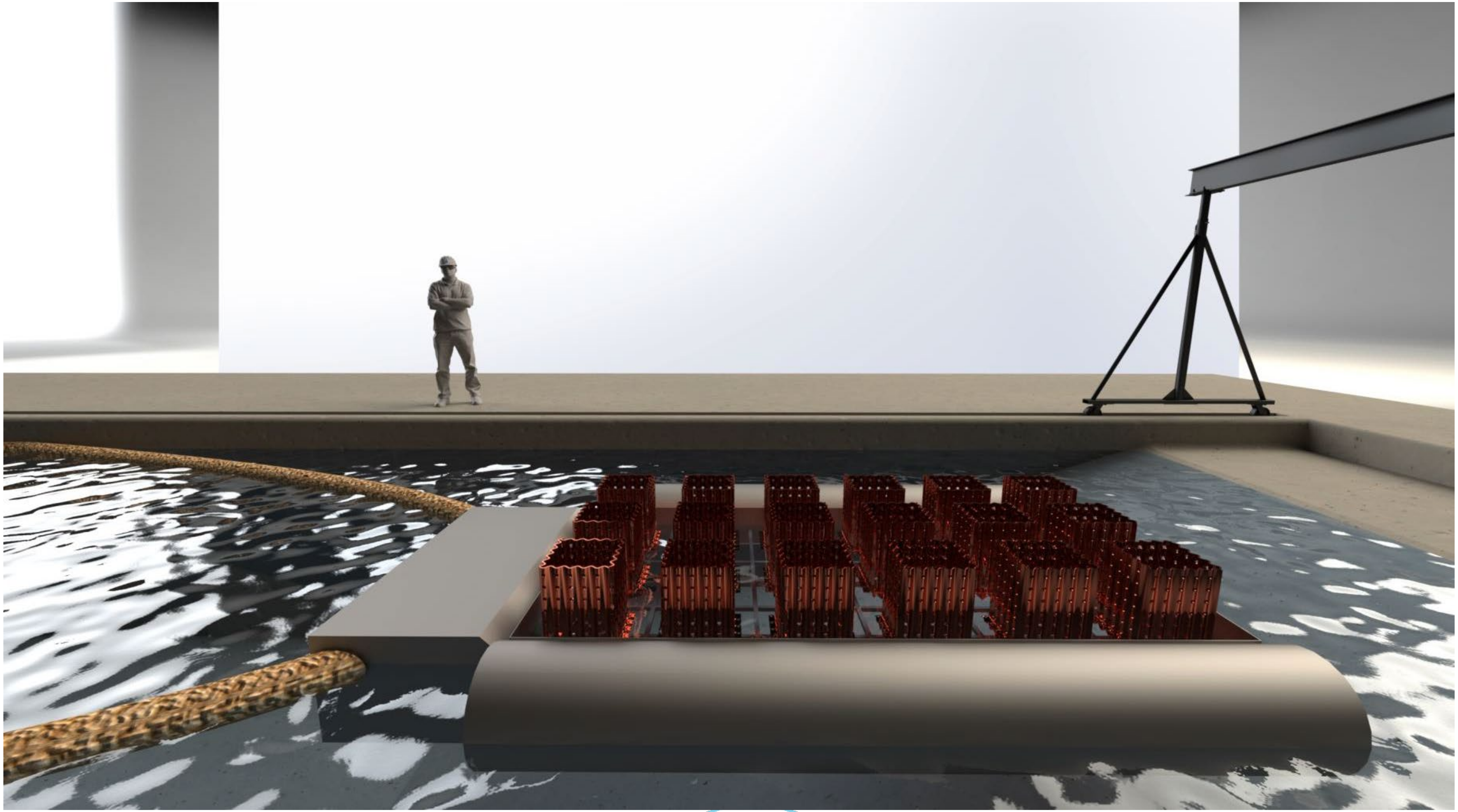
BSEE– Floating Flame Refluxer™ Technology

Objective:

This study aims to develop a floating Flame Refluxer™ attachable to the newly designed gate of an Elastec fire boom for ISB of an oil slick in an offshore environment. The target burning rate per unit area is 2 to 5 times baseline values with an improvement in emissions (30 – 60% reduction in CO/CO_2 ratio) resulting in reduced black smoke during combustion.







BSEE
Bureau of Safety and Environmental Enforcement