# In Situ Burning – An Overview

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# Outline

- How In-Situ Burning Works
- Why Burn?
- IOGP-IPIECA Work Products (IPIECA -*International Petroleum Industry Environmental Conservation Association)*
- API ISB Work Products
- *Soil Heating*
- *Ignition Enhancement*
- *Equipment Selection*
- *Good Practice Guidance*
- *Operational Guidance*
- *Decision Making*
- *Safety and industrial Hygiene*
- *Emissions Comparison*
- *Selection and Training of ISB personnel*
- *ISB Fact Sheets*

# How In-Situ Burning Works

**DEFINITION**: *ISB removes spilled oil from a land, snow, ice, or water surface by combustion of hydrocarbon vapors and yields predominantly $CO_2$ and water to the atmosphere*.

- Burning occurs in the vapor phase as hydrocarbons evaporate
  - The middle of a fire may be 1000$^{o}$C or higher
  - The surface of oil must remain above 400$^{o}$C to sustain a burn
- Depending on slick thickness, high removal rates can be achieved
  - Typically, burns are short lived (minutes to hours)
- Natural gas blowouts burn completely, but oils do not
  - Incomplete combustion can lead to black smoke
  - Smoke is predominantly carbon particulates
- High-density residues can remain after a burn
  - Relatively inert, i.e., not bioavailable, and easy to collect on land
  - Can sink or submerge and be difficult to recover for spills on water

# Why Burn?

**Advantages**

- Good for remote regions or those with difficult access
  - Less equipment and labor required
- Minimizes intrusive impacts from mechanical response on sensitive habitats
- Can be used on water, on ice, and on land
- High efficiency removal rates (up to 98-99%) of encountered oil
  - Areas can be re-burned, as needed
  - Much less waste for disposal


**Constraints**

- Limited window-of-opportunity on open water
  - Emulsified oils do not burn well (difficult when water content >30%)
- Minimum thickness required to ignite and sustain a burn
- Residue can be difficult to recover (can submerge / sink)
- Smoke plume is an aesthetic issue and particulates may be a health concern
- Fire booms for on-water burns have limited life, but during Macondo, boom could be used in number of burns lasting for hours
- Possible risk of fire spreading (safety)

# IOGP-IPIECA Work Products

- **Guidelines for the selection of ISB equipment**
- Document on ISB residues and plumes (CEDRE & INERIS)
- **Good Practice Guide – Controlled ISB of spilled oil**

*Note: Work products in **bold** will be discussed in further detail*

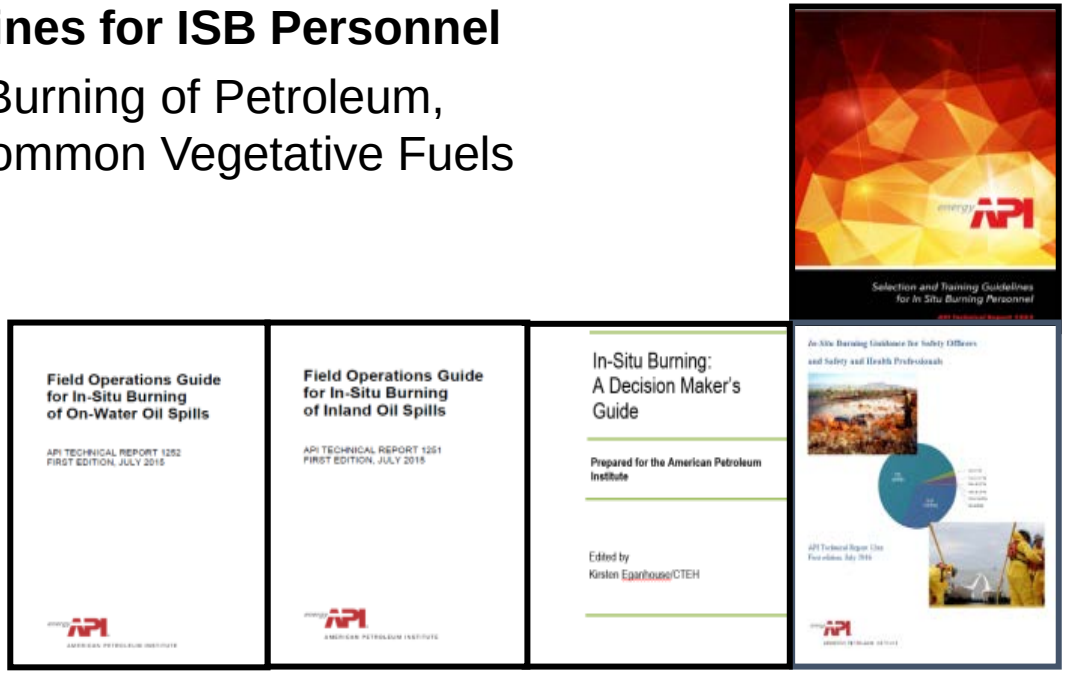

(IPIECA -*International Petroleum Industry Environmental Conservation Association)*

*(International Oil and Gas Producers)*

# API ISB Work Products

- **ISB: A Decision Maker's Guide**
- **Field Operations Guides for ISB of Inland and On-Water Spills**
- **Fact Sheet Series**
- **ISB Guidance for Safety Officers and Safety and Health Professionals**
- ISB SH FAQs
- **Selection and Training Guidelines for ISB Personnel**
- Comparison of Emissions from Burning of Petroleum, Petroleum-Derived Fuels and Common Vegetative Fuels
- **Soil Heating from ISB**
- **Ignition Enhancement**

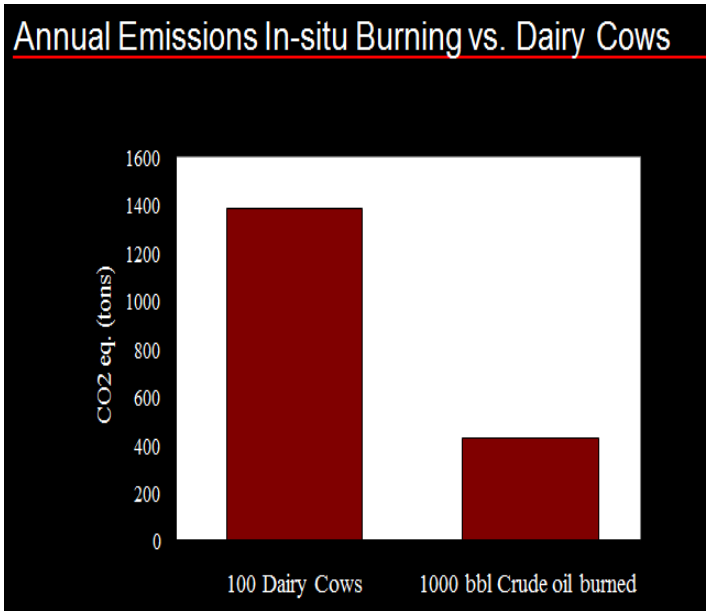
*Note: Work products in **bold** will be discussed in further detail*

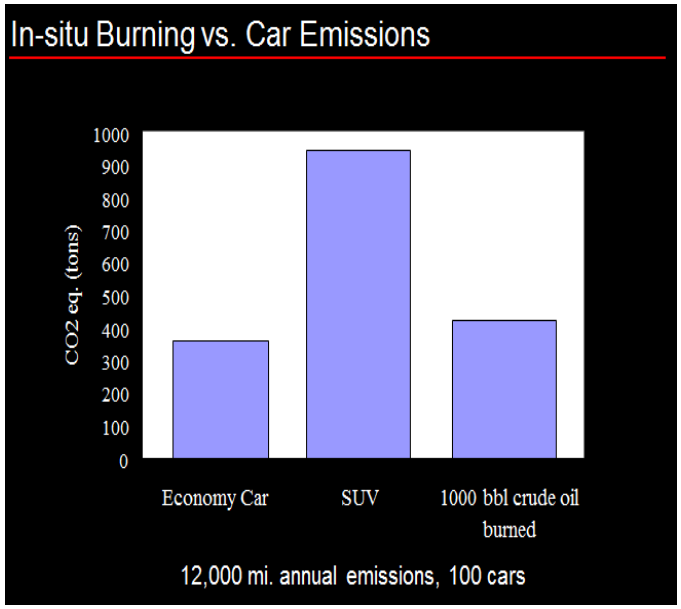


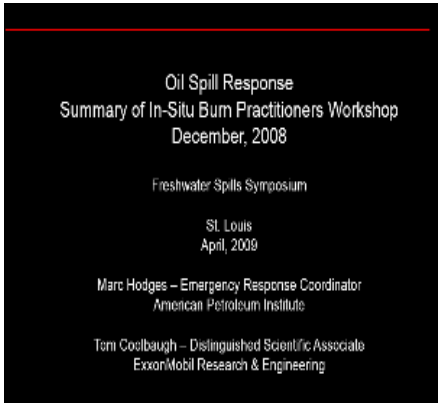

(*American Petroleum Institute)*

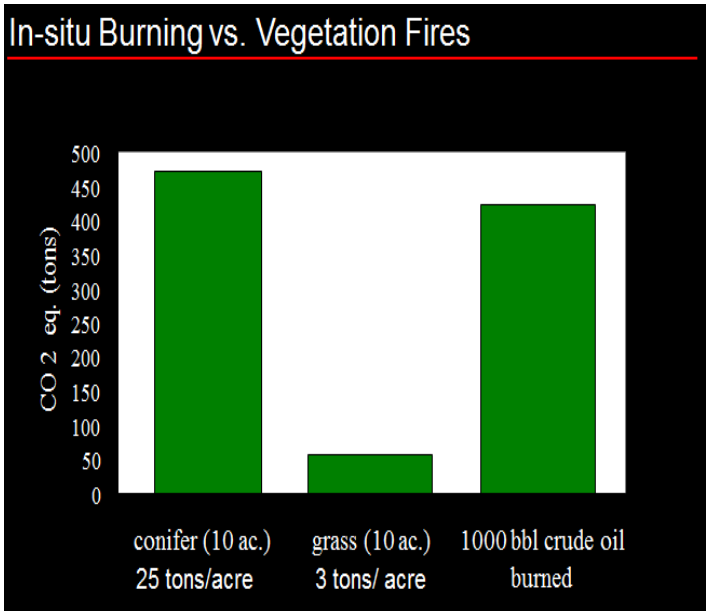
# Past API Focus on ISB

- Considered emissions compared to:
  - Wild fires
  - Car emissions
  - Cow emissions
- $CO_2$ is the major GHG from ISB
- Aerosol and soot from ISB are not significant cooling contributors
- 1000 bbl ISB is equivalent to a 10-acre wildfire (25 tons/acre) in terms of GHG emissions



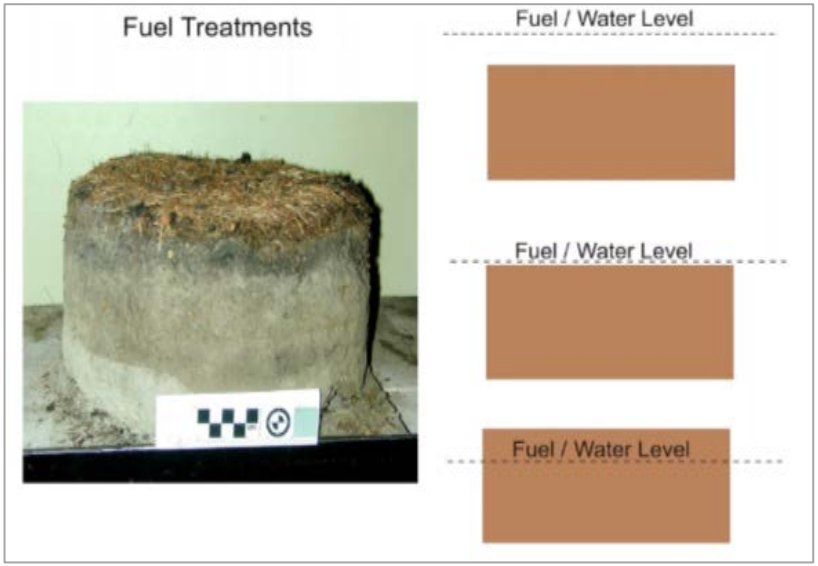



# Soil Heating from In-situ Burning

- **Objective**: Conduct soil heating tests on possible effects to soils and plants from ISB
  - Core burns to measure soil heating with a variety of soils, moisture conditions (wet, dry, standing water), and petroleum products
  - Develop a fire behavior module from ISB based on 'USFS' First Order Fire Effects Model
- Potential for higher heat profile (BTU) with hydrocarbons versus forest fires
- Different temperature profiles at different soil depths




*2 oil types with 3 soil moisture levels tested*

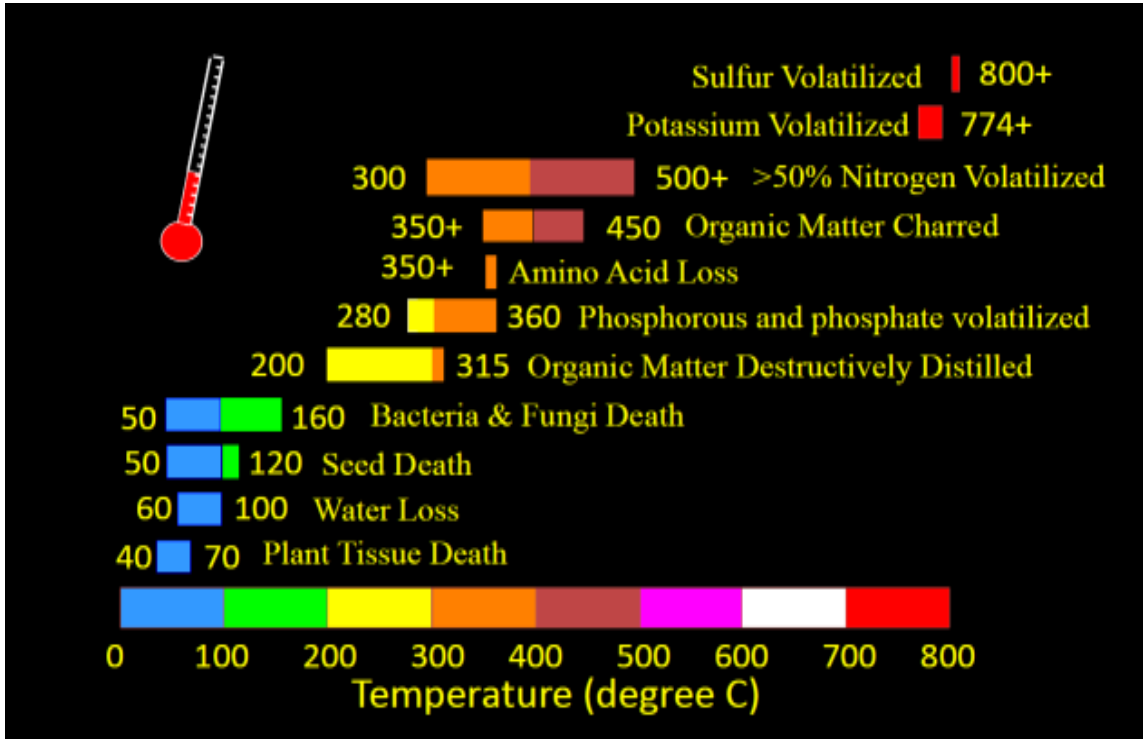
Figure 3. One of the Soil Core Test Burns.

http://www.interspill.org/previous-events/2015/WhitePapers/Interspill2015ConferenceProceedings/24-MARCH-2015/Inland%20Spills/In-Situ-Burning-and-Soil-Heating-J-Myers-Chevron-A-Steen-ExxonMobil.pdf

# Soil Heating from In-situ Burning

**Conclusions**

- Aligned with wildfire fire behavior model for heat transfer
- Maximum soil temperatures were **below** threshold expected to negatively effect plants and soils – suggesting **soil sterilization does not occur**
- Saturated soils, with **water at soil surface could insulate against ISB heat**; standing water is unnecessary
- Developed ISB module to estimate heat effects for burn planning.
- Post-burn soil $CO_2$ respiration rates were slightly heightened



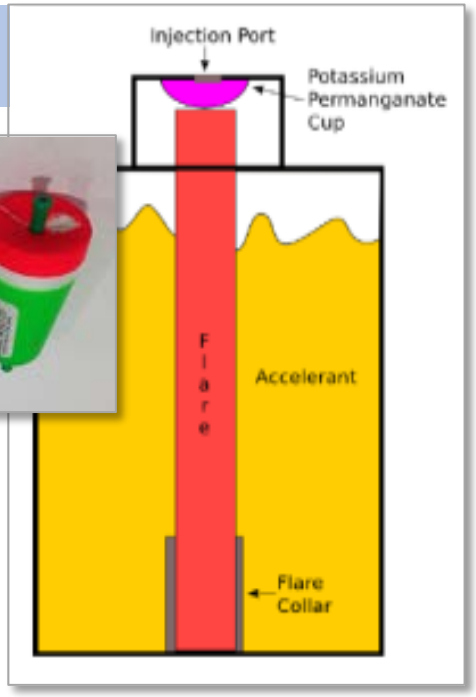

*Known range of effects on plants and soils with increasing temperature*

# Ignition Enhancement

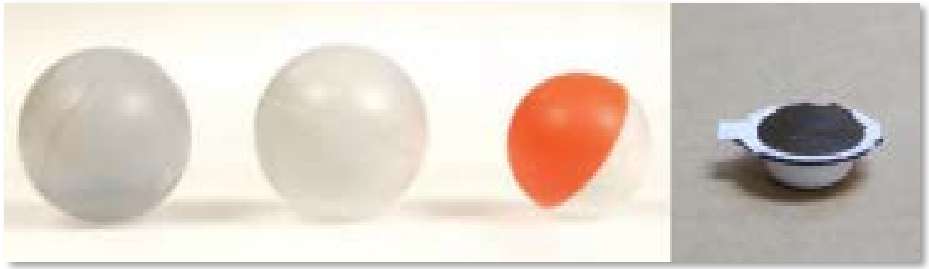
**Objective**: Evaluate ignition devices and aircraft to improve safety, burn reliability, targeting

- Scope:
  - Examine performance of existing ignition systems
  - Work with manufactures on testing and improvements for aerial ignition (fixed and rotary wing platforms); Potential to develop new or modified igniters

*Proposed Igniters:*




- Stays upright
- 'Dunkable'
- Waterproof
- Floats
- Access to oxygen

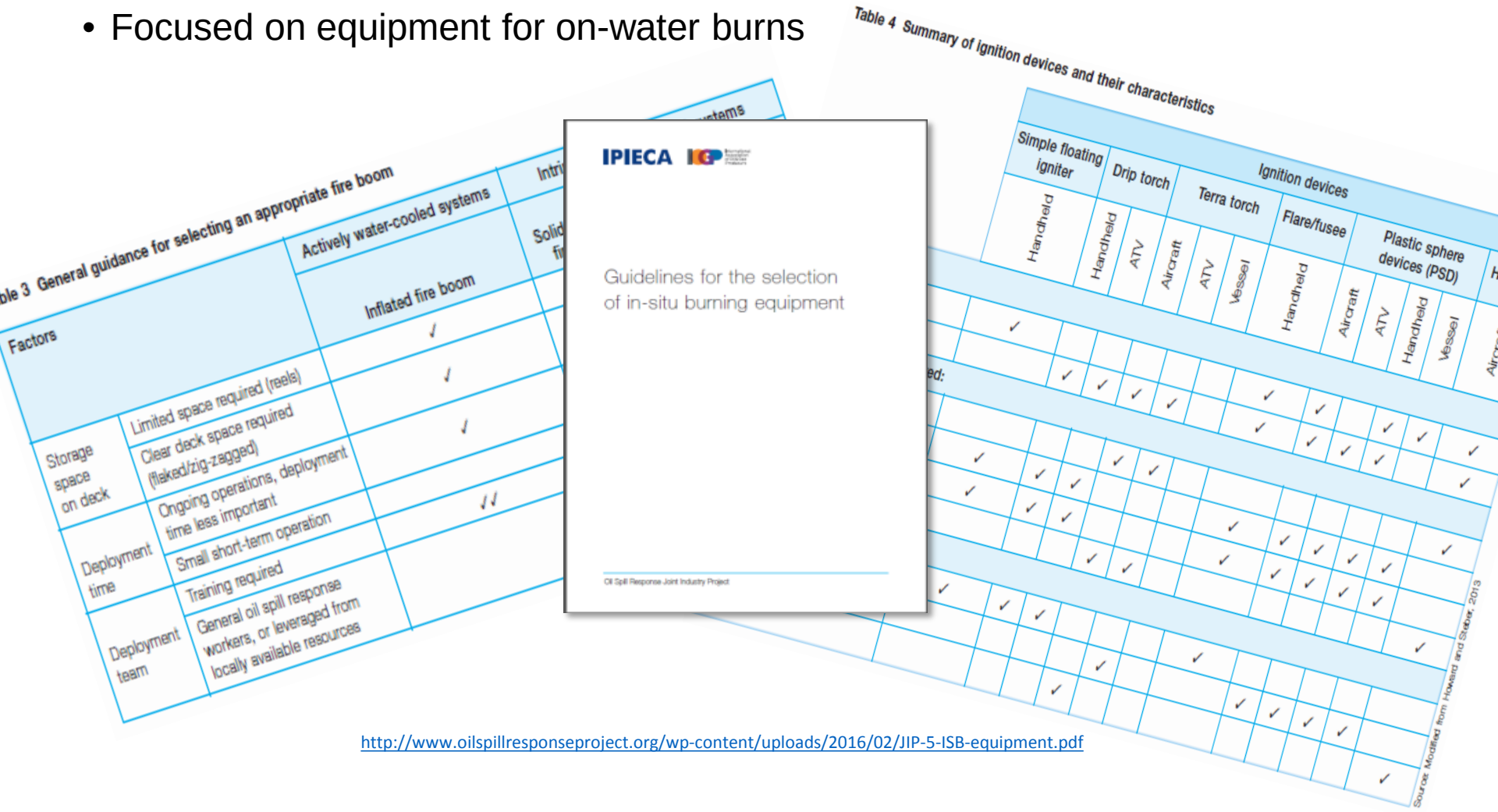


$KMnO_4$ capsules: Premo, Aerostat, SEI Dragon Egg, and Raindance R3

# ISB Equipment Selection Guidelines

**Objective:** Compile and summarize equipment efficiency information for use by operators, responders and regulators.

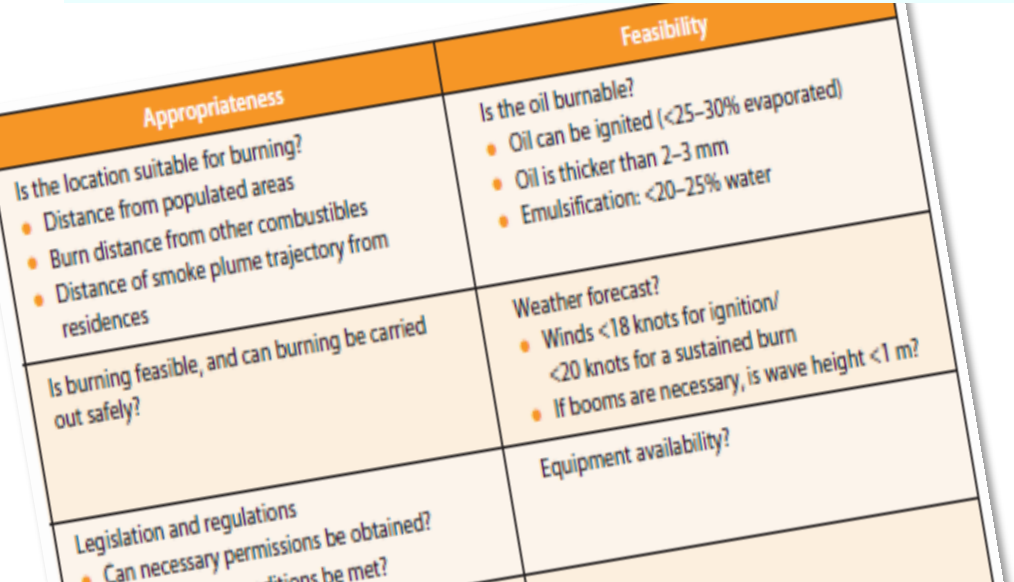
- Focused on equipment for on-water burns



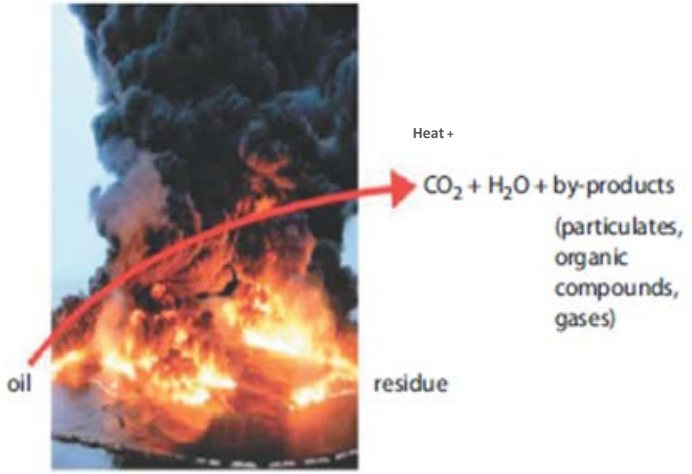

http://www.oilspillresponseproject.org/wp-content/uploads/2016/02/JIP-5-ISB-equipment.pdf

# ISB Good Practice Guide Content Synopsis

| | |
|---|---|
| ***Science of burning*** | Ignitable vapors, combustion and oil removal rates |
| ***Decision-making*** | Use of NEBA, typical regulatory approvals before use, health and environmental issues, feasibility of use |
| ***Application*** | On-land and on-water spills, hazards (e.g. , smoke plumes), planning and execution |
| ***Equipment*** | Igniters, ignition platforms, booms, support vessels and aircraft |
| ***Monitoring*** | Heat, emissions, fire control, habitat recovery |
| ***Appendices*** | 1. Oil removal and efficiency estimation<br>2. Boom deployment and towing configurations |



| Appropriateness | Feasibility |
|---|---|
| Is the location suitable for burning?<br>• Distance from populated areas<br>• Burn distance from other combustibles<br>• Distance of smoke plume trajectory from residences | Is the oil burnable?<br>• Oil can be ignited (<25–30% evaporated)<br>• Oil is thicker than 2–3 mm<br>• Emulsification: <20–25% water |
| Is burning feasible, and can burning be carried out safely? | Weather forecast?<br>• Winds <18 knots for ignition/ <20 knots for a sustained burn<br>• If booms are necessary, is wave height <1 m? |
| Legislation and regulations<br>• Can necessary permissions be obtained? | Equipment availability? |

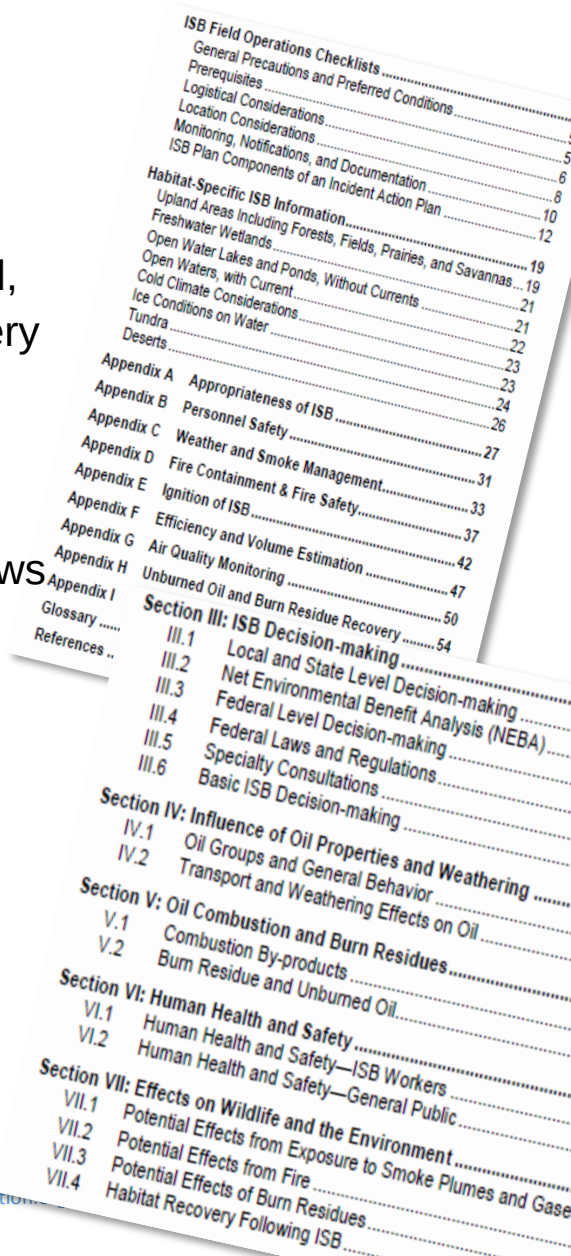



http://oilspillresponseproject.org

# API Operational Guides and Decision Making

- ISB **Operational Guides: On-water and Inland**
  - Objective: provide operational guidance for burn execution
  - Concise, booklet format
  - Checklists provided and Red Flag conditions noted
  - Appendices on weather and smoke mgmt., ignition, fire control, removal estimates, air quality monitoring, and residue recovery

- Updated: **Decision-Making** publication
  - Objective: update 1995 API publication post-DWH
  - US local, state, and federal decision-making processes; US laws and regs.
  - Includes oil weathering, health and safety, wildlife and environment


http://www.oilspillprevention

# Safety and Industrial Hygiene Guidelines

- Types of ISB emissions
  - Smoke plumes often of greatest concern for responders and public, though actual health risks from ISB likely minimal
- ISB hazards: working environment
  - Latest exposure thresholds for key gases, VOCs, and particulates
  - ISB emissions exposure thresholds
  - For each hazard (chemical or physical), risks and control measures are ID'd
- ISB incident templates
  - Safety and Health plan
  - 'Job Safety Analysis' forms
- Safety Officer performance qualifications
  - Aligned with API ISB Selection & Training

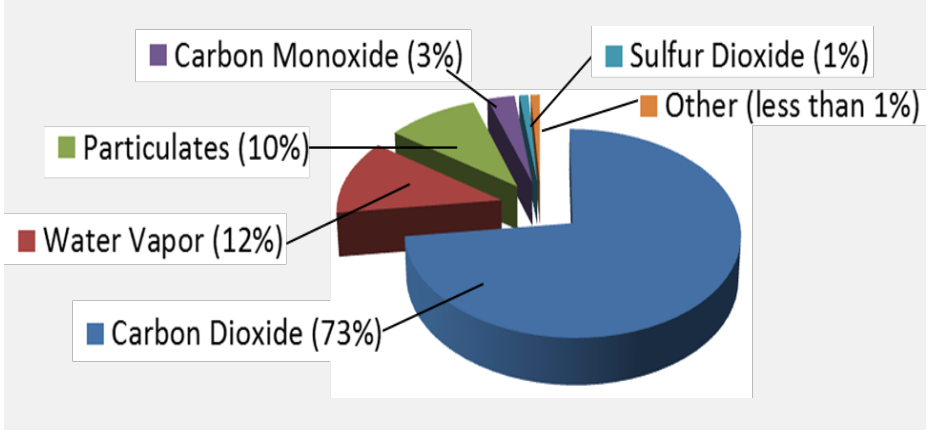



**Figure 2.** Typical Combustion by-products from burning crude oil. Source: modified from (Ferek, 1997)

# Working-Environment Safety & Health Information

**Table 9. Hazards and Control Measures for Smoke Plumes**

| Hazard | Risk/Effect | Controls |
|---|---|---|
| Black smoke[a] (Moderate to High Risk) | Loss of ability to see other responders or operations | A, B, C, D, E, F, G, H, I, J, K, L, M, N, O, Q |
| | Disorientation | |
| | Concern of public and responders as to their health and health of environment | |
| | Create shorting or grounding in high voltage power lines | |
| Airborne smoke particulates (soot)[b] (Moderate to High Risk) | Fine PM is small enough to access the gas exchange regions of the lung when inhaled | A, B, C, D, E, F, G, H, I, J, K, L, M, N, O |
| | At moderate to high concentrations it is an eye, nose and respiratory irritant | |
| | High concentrations can cause persistent cough, phlegm, wheezing, and difficulty breathing | |
| | May be transported considerable distances from the combustion source, resulting in potential inhalation exposures for a wider area of the public | |
| | EPA NAAQS PM levels may be exceeded | |
| Additional combustion by-products[c] (Moderate Risk) | Levels of CO could be high in plume. Past monitoring has not found CO to be an issue if there is no entry into the plume | A, B, C, D, E, F, G, H, I, J, K, L, M, O |
| | Overexposure to CO may result in headache, nausea, dizziness, confusion and at high levels, asphyxia and death | |

**Control Measures Key** (Examples):

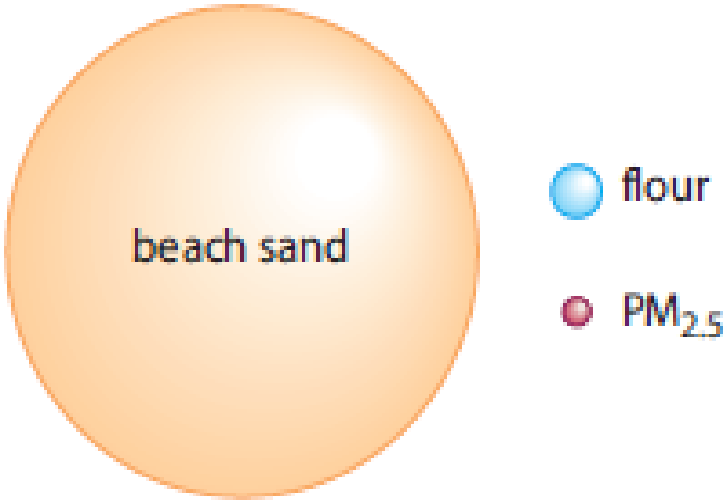
**C** – Train personnel to never position themselves or their teams immediately downwind of smoke plume.

**H** – Ensure communications plan is in place and meets needs of responders and support teams.

# Emissions Comparison Findings

- Primary ISB emissions of health concern are coarse ($PM_{10}$) and fine ($PM_{2.5}$) particulate matter and PAHs.
  - Total emissions reflect emissions rate and amount of fuel (hydrocarbon or vegetative) consumed
- ISBs are typically short-duration events lasting minutes to hours
- ISB airborne emissions factors are similar to natural or intentional burning of plant matter
  - ISB of crude produces $PM_{2.5}$ and PAHs potentially similar to wildfires and controlled agricultural burning

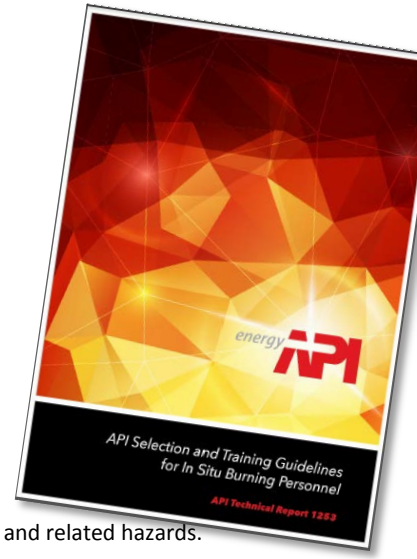
**Figure 1** *Relative particle sizes*
(based on data courtesy of the National Wildfire Coordination Group)



# Selection and Training of ISB Personnel

**Objective**: Guidelines for ISB responders

- Covers ISB operations for terrestrial, open water, and on-ice burns
  - IDs competencies, performance requirements, knowledge, and skills
  - Based on NFPA[1] approach for competence with hazardous materials (#472)
  - Aligned with OSHA standard for responders (#3172)
  - 10 ISB jobs with specific performance expectations and duties




[1] Founded in 1896, NFPA is a global, nonprofit organization devoted to eliminating death, injury, property and economic loss due to fire, electrical and related hazards. NFPA delivers information and knowledge through >300 consensus codes and standards, research, training, education, outreach and advocacy.

# Selection and Training of ISB Personnel, con't

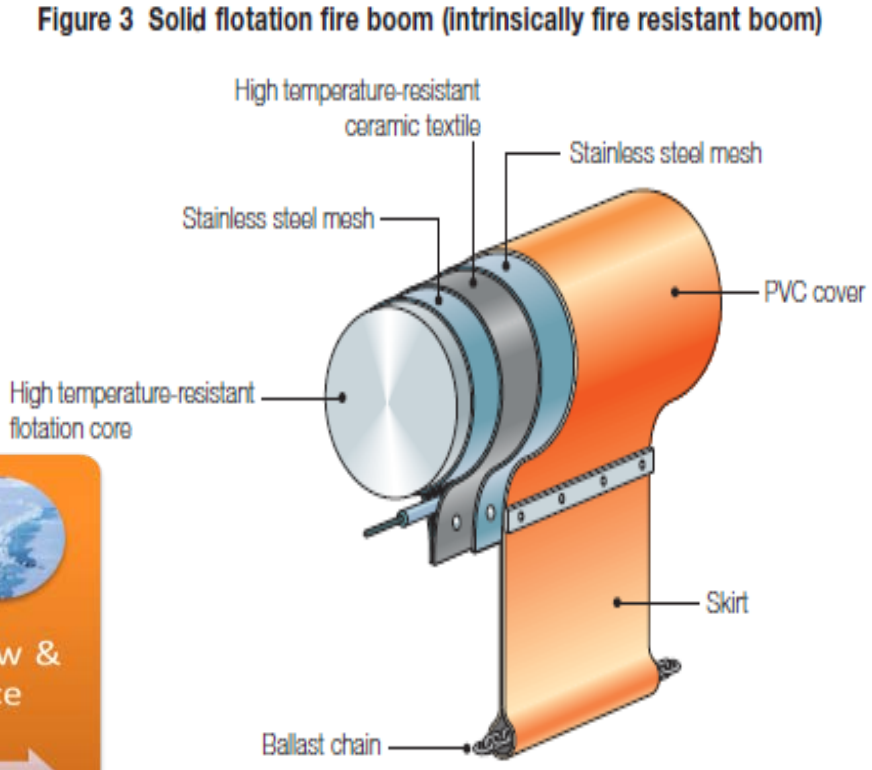
- Competency categories: analyze, plan, execute, evaluate, terminate, and training/physical fitness
- Selection and training principles
  - Flexible, so training can be adjusted to fit circumstances and needs
  - Acceptance of job experience in lieu of training

# Position: Competency Matrix

| Position → ---------- Competency↓ | Burn Boss | Safety Officer | Vessel Captain | Fire Fighter | Ignition Specialist | Deck Hand Small Boat Operations | Air Monitoring | Skilled Support | Aerial Survey | Observer |
|---|---|---|---|---|---|---|---|---|---|---|
| Oil Hazards | X | X | X | X | X | X | X | X | X | X |
| Sensitive Resources | X | | X | X | X | | | X* | X | X* |
| Risk to Environment | X | | | | | | | X* | | X* |
| Task Force Tactics | X | X | X | X | X | X | X | X* | X | X |
| Vessel Navigation | | | X | | | | | | | |
| Vessel Handing | | | X | | | | | | | |
| Small Boat Safety | X | X | X | | X | X | X | X* | | |
| Spill Control Agent Usage | X | X | | | X | | | | | |
| PPE | X | X | X | X | X | X | X | X | | X |
| On-Water Ignition | X | X | X | | X | | | | | |
| Ignition on Land / Ice | X | X | | | X | | | | | |
| Aerial Ignition | X | X | | | X | | | | | |
| Ops Briefing | X | X | X | X | X | X | X | X | X | X |
| Boom Deployment | X | X | X | | X | X | | | | |
| Boom Towing | | X | X | | | X | | | | |
| Deck Hand Small Boat | X | | X | | X* | X | X* | X* | | |
| Fire Fighting | X | X | X | X | X | X | X | X* | | |
| First Aid | X* | X* | X* | X* | X* | X* | X* | X* | | |
| Air Monitoring | X | X | | | | | X | | | |
| Aerial Survey | X | | | | | | | | X | |
| Worker Exposure | X | X | X | X | X | X | X | X | X | X |
| Response critique | X | X | X | X | X | X | X | X | X | |
| Impact to Environment | X | | | | | | X | X* | | |
| OSHA HAZWOPER | 24 | 24 | 8 to 24 | 24 | 24 | 8 to 24 | 24 | 24 | Briefing | Briefing |

# ISB Fact Sheet Series

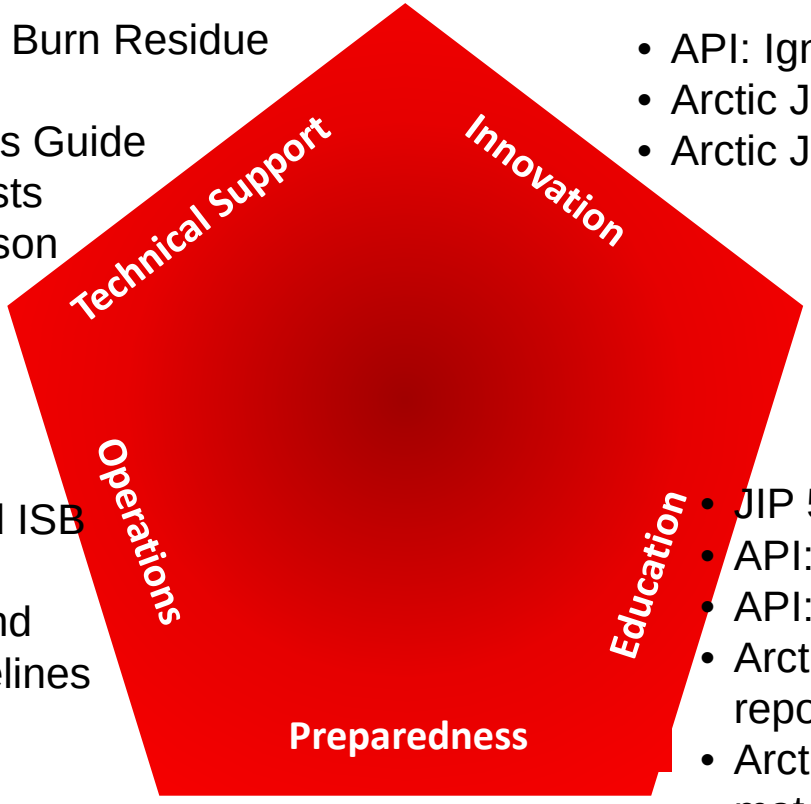
- Multi-page, high-level documents for public consumption
  - Introduction to ISB
  - Fate of burned oil
  - ISB human health and environmental effects
  - Assessing ISB benefit and risks
  - ISB approval in the U.S.
  - ISB operations

# Synopsis of ISB Topics

- JIP 5: Smoke Plume and Burn Residue Evaluation
- API: ISB Decision-Makers Guide
- API: ISB Soil Heating Tests
- API: Emissions Comparison

- API: Ignition Enhancement
- Arctic JIP: Herder Field Tests
- Arctic JIP: Aerial Ignition Systems




- API: On-Water and Inland ISB Operations Guides
- API: ISB Safety Officer and Industrial Hygienist Guidelines

- JIP 5: ISB Good Practice Guide
- API: ISB Fact Sheets
- API: ISB Safety and Health FAQs
- Arctic JIP: State of Knowledge reports
- Arctic JIP: Herder educational materials

- JIP 5: Equipment Selection
- API: ISB Responder Selection and Training Guidelines

http://www.oilspillprevention.org/oil-spill-cleanup/oil-spill-cleanup-toolkit/in-situ-burning

http://www.oilspillresponseproject.org/response/in-situ-burning/

# Any burning questions?